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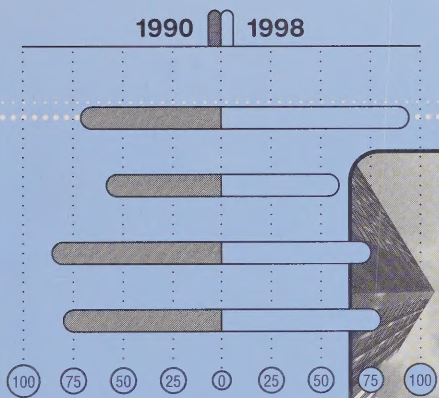
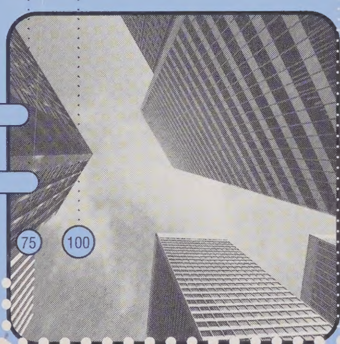
Office of Energy Efficiency

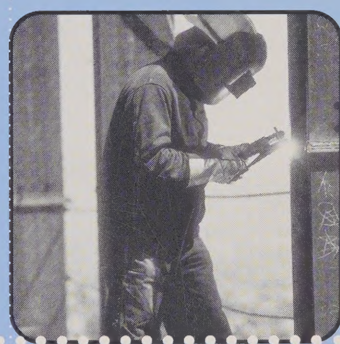
Energy Efficiency Trends in Canada 1990 to 1998

A Review of Secondary Energy Use, Energy Efficiency and Greenhouse Gas Emissions

October 2000







Trends 1990-1998

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Preface

This report is the fifth annual review of trends in energy use, energy efficiency and greenhouse gas (GHG) emissions in Canada, using 1990 as the baseline year.

Energy Efficiency Trends in Canada 1990 to 1998 differs from the previous four reports in a number of ways:

- it addresses the period from 1990 to 1998;
- it incorporates the greenhouse gases nitrous oxide (N_2O) and methane (CH_4) along with carbon dioxide (CO_2), in the calculation of greenhouse gas emissions from secondary energy use; previous reports reported CO_2 emissions only.
- it uses a number of improved data sources and analytical methodologies;
- the analysis of the industrial sector is based on 40 industries, compared to 39 in last year's report;
- it measures activity in the residential sector using the number of households in Canada and the total floor area of dwellings; and
- the Office of Energy Efficiency (OEE) Index is reported in terms of energy efficiency improvements rather than energy efficiency effects.

As was the case with previous reports, the intent is to provide the reader with a detailed description of the framework, methodology and data sources used for the review. A database containing all energy indicators calculated for this report is available on the Internet by searching for *Energy Efficiency Trends in Canada* at http://oee.nrcan.gc.ca/dpa/analysis_e/trends.cfm

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Contents

Preface I

List of Figures and Tables VII

Executive Summary XI

Chapter 1 – Scope of the Report **001**
- 1.1 The Relationship Between Secondary Energy Use and Greenhouse Gas Emissions 002
- 1.2 Structure of the Analysis 003
- 1.3 The Data 005
- 1.4 Overview of the Report 007

Chapter 2 – Economy-Wide Trends in End-Use Energy, Energy Efficiency and Greenhouse Gas Emissions **009**
- 2.1 Overview – Energy Use and Greenhouse Gas Emissions 009
- 2.2 Trends in Energy Use and Greenhouse Gas Emissions 010
- 2.3 Trends in the Greenhouse Gas Intensity of Secondary Energy Use 013

Chapter 3 – Residential Sector **015**
- 3.1 Overview – Energy Use and Greenhouse Gas Emissions 015
- 3.2 Trends in Energy Use 016
  - *3.2.1 Factors Contributing to Changes in Energy Use 019*
  - *3.2.2 Factors Influencing Space Heating Energy Use 020*
  - *3.2.3 Factors Influencing Appliance Energy Use 023*
  - *3.2.4 Factors Influencing Other Energy End-Uses 028*
- 3.3 Trends in Greenhouse Gas Emissions 028
- 3.4 Trends in Carbon Dioxide Emissions 030
- 3.5 The Data Situation 032

Chapter 4 – Commercial Sector **033**
- 4.1 Overview – Energy Use and Greenhouse Gas Emissions 033
- 4.2 Trends in Energy Use 034
  - *4.2.1 Factors Contributing to Changes in Energy Use 035*
  - *4.2.2 The Influence of Growth in Commercial Activity –The Activity Effect 036*
  - *4.2.3 The Influence of Fluctuations in Climatic Conditions –The Weather Effect 037*
  - *4.2.4 The Influence of Shifts in the Mix of Building Types – The Structure Effect 037*
  - *4.2.5 The Influence of Variations in the Energy Efficiency of Commercial Energy Use – The Energy Efficiency Effect 037*
- 4.3 Trends in Greenhouse Gas Emissions 040
- 4.4 The Data Situation 041

Chapter 5 – Industrial Sector **043**
5.1 Overview – Energy Use and Greenhouse Gas Emissions 043
5.2 Trends in Energy Use 046
5.2.1 Factors Contributing to Changes in Energy Use *046*
5.2.2 The Influence of Growth in Industrial Activity – The Activity Effect *048*
5.2.3 The Influence of Shifts in the Distribution of Industrial Activity – The Structure Effect *049*
5.2.4 The Influence of Variation in the Energy Efficiency of Industrial Energy Use – The Energy Efficiency Effect 049
5.3 Industry-by-Industry Analysis 051
5.3.1 Beverage Industry *051*
5.3.2 Brewery Products Industry *052*
5.3.3 Electrical and Electronic Products Industry *052*
5.3.4 Iron and Steel Industry *052*
5.3.5 Other Paper Industries *052*
5.3.6 Petroleum Refining Industry *053*
5.3.7 Primary Production of Aluminum Industry *053*
5.3.8 Primary Textile Industry *054*
5.3.9 Pulp Industry *054*
5.3.10 Rubber Products Industry *054*
5.4 Trends in Greenhouse Gas Emissions 055
5.5 The Data Situation 058

Chapter 6 – Transportation Sector **059**
6.1 Overview – Energy Use and Greenhouse Gas Emissions 059
6.2 Trends in Energy Use 061
6.3 Trends in Passenger Transportation Energy Use 061
6.3.1 Factors Contributing to Changes in Energy Use – Passenger Transportation *062*
6.3.2 Light Vehicles *063*
6.3.3 Buses *065*
6.3.4 Rail *066*
6.3.5 Aviation *066*
6.4 Trends in Freight Transportation Energy Use 066
6.4.1 Factors Contributing to Changes in Energy Use – Freight Transportation *068*
6.4.2 Freight Trucks *068*
6.4.3 Rail *070*
6.4.4 Marine *070*
6.5 Trends in Greenhouse Gas Emissions 070
6.6 The Data Situation 072

Chapter 7 – Agriculture Sector **075**
7.1 Overview – Energy Use and Greenhouse Gas Emissions 075
7.2 Trends in Energy Use 076
7.2.1 Factors Contributing to Changes in Energy Use *076*
7.2.2 The Activity Effect *076*
7.2.3 The Aggregate Energy Intensity Effect *077*
7.3 Trends in Greenhouse Gas Emissions 078
7.4 The Data Situation 079

Appendix A – Data Presented in Report (including data sources for each figure) **081**

Appendix B – Types of Indicators **107**

Appendix C – Methodology and Data Sources for the Energy Use Factorization Analysis **109**

Appendix D – Reconciliation of Data on Energy Use Found in This Report with Statistics Canada's *Quarterly Report on Energy Supply-Demand in Canada Data* (CANSIM) – *1998* **125**

Appendix E – Reconciliation of Definition of Estimated Greenhouse Gas Emissions Found in This Report with Environment Canada's *Canada's Greenhouse Gas Inventory: 1997 Emissions and Removals with Trends* **127**

Appendix F – Greenhouse Gas Emissions Trends Analysis **129**

Appendix G – Glossary of Terms **131**

List of Figures and Tables

List of Figures

Figure 1.1: The Relationship Between Secondary Energy Use and Greenhouse Gas Emissions 002

Figure 1.2: Residential Sector Floor Space Services Indicator Pyramid 003

Figure 1.3: The OEE Energy Efficiency Index, 1990–1998 004

Figure 2.1: Secondary Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 010

Figure 2.2: Secondary Energy Fuel Shares, 1990 and 1998 011

Figure 3.1: Distribution of Floor Space by Type of Dwelling, 1998 015

Figure 3.2: Distribution of Residential Energy Use by End-Use, 1998 015

Figure 3.3: Residential Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 016

Figure 3.4: Residential Energy Fuel Shares, 1990 and 1998 017

Figure 3.5: Residential Energy End-Use Shares, 1990 and 1998 017

Figure 3.6: Average Floor Area of Dwellings by Vintage 018

Figure 3.7: Households and Floor Area Evolution, 1990–1998 019

Figure 3.8: Factors Influencing Growth in Residential Energy Use, 1990–1998 019

Figure 3.9: Factors Influencing Growth in Residential Space Heating Energy Use, 1990–1998 020

Figure 3.10: Housing Stock Floor Area by Vintage, 1990 and 1998 021

Figure 3.11: Natural Gas Furnace Stocks by Efficiency Level, 1990 and 1998 022

Figure 3.12: Factors Influencing Growth in Residential Appliance Energy Use, 1990–1998 022

Figure 3.13: Penetration Rates for Household Appliances, 1990 and 1998 024

Figure 3.14: Energy Efficiency Trends of Appliances, 1990 and 1998 025

Figure 3.15: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Residential Sector, 1990–1998 029

Figure 3.16: Residential Greenhouse Gas Emissions by Fuel Type, 1998 029

Figure 3.17: Residential Greenhouse Gas Emissions by End-Use, 1990 and 1998 030

Figure 3.18: Growth in Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, Residential Sector, 1990–1998 . . . 031

Figure 3.19: Residential Carbon Dioxide Emissions by Fuel Type, 1998 031

Figure 4.1: Distribution of Commercial Energy Use by End-Use, 1998 033

Figure 4.2: Distribution of Commercial Energy Use by Fuel Type, 1998 034

Figure 4.3: Distribution of Commercial Energy Use and Activity by Building Type, 1998 034

Figure 4.4: Commercial Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 035

Figure 4.5: Factors Influencing Growth in Commercial Energy Use, 1990–1998 036

Figure 4.6: Annual Growth of Commercial Floor Space and RDP with a 3-Year Lag, 1990–1998 036

Figure 4.7: Changes in Commercial Activity Shares by Building Type, 1990–1998 037

Figure 4.8: Commercial Sector Employment by Floor Space, 1990–1998 039

Figure 4.9: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Commercial Sector, 1990–1998 . . . 040

Figure 4.10: Commercial Energy Fuel Shares, 1990 and 1998 040

Figure 4.11: Commercial Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, 1990–1998 041

Figure 5.1: Distribution of Energy Use and Activity (as measured by GDP) by Industry, 1998 045

Figure 5.2: Industrial Energy Use, Aggregate Energy Efficiency, Activity and Energy Efficiency, 1990–1998 046

Figure 5.3: Factors Influencing Growth in Industrial Energy Use, 1990–1998 047

Figure 5.4: Changes in Sectoral Shares of Industrial Activity, 1990–1998 050

Figure 5.5: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Industrial Sector, 1990–1998 055

Figure 5.6: Industrial Greenhouse Gas Emissions by Industry, 1990 and 1998 056

Figure 5.7: Industrial Energy Fuel Shares, 1990 and 1998 057

Figure 5.8: Industrial Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, 1990–1998 057

Figure 6.1: Distribution of Passenger Transportation Energy Use and Activity by Mode, 1998 060

Figure 6.2: Distribution of Freight Transportation Energy Use and Activity by Mode, 1998 060

Figure 6.3: Passenger Transportation Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 061

Figure 6.4: Passenger Transportation Fuel Shares, 1990 and 1998 062

Figure 6.5: Passenger Transportation Energy Mode Shares, 1990 and 1998 062

Figure 6.6: Factors Influencing Growth in Passenger Transportation Energy Use, 1990–1998 063

Figure 6.7: Factors Influencing Growth in Light Vehicle Passenger Transportation Energy Use, 1990–1998 064

Figure 6.8: New Car Fuel Economy, Normalized for Weight and Power, 1990–1998 065

Figure 6.9: Freight Transportation Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 067

Figure 6.10: Freight Transportation Fuel Shares, 1990 and 1998 067

Figure 6.11: Factors Influencing Growth in Freight Transportation Energy Use, 1990–1998 068

Figure 6.12: Factors Influencing Growth in Road Freight Transportation Energy Use, 1990–1998 069

Figure 6.13: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Transportation Sector, 1990–1998 . . . 071

Figure 6.14: Transportation Greenhouse Gas Emissions Shares by Mode, 1990 and 1998 . . 071

Figure 6.15: Transportation Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, 1990–1998 . . . 072

Figure 7.1: Distribution of Agricultural Energy Use by Fuel Type, 1998 . . . 075

Figure 7.2: Agricultural Energy Use, Aggregate Energy Intensity and Activity, 1990–1998 . . . 076

Figure 7.3: Agricultural Energy Fuel Shares, 1990 and 1998 . . . 077

Figure 7.4: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Agricultural Sector, 1990–1998 . . . 078

Figure 7.5: Agriculture Greenhouse Gas Emissions by Fuel Type, 1998 . . . 078

Figure 7.6: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Agricultural Sector, 1990–1998 . . . 079

List of Tables

Table 1.2: Definitions of Activity and Structure Used in This Report, by Sector . . . 004

Table 2.1: Sectoral Energy Distribution and Associated Greenhouse Gas Emissions, 1998 . . . 009

Table 2.2: Sectoral Activity, Energy Use and Greenhouse Gas Emissions Growth 1990–1998 . . . 010

Table 2.3: Share of Carbon Dioxide in Total Greenhouse Gas Emissions, by Sector, 1990 and 1998 . . . 011

Table 2.4: Factors Influencing Growth in Secondary Energy Use, 1990–1998 . . . 012

Table 2.5: Factors Influencing Growth in Greenhouse Gas Emissions from Secondary Energy Use, 1990–1998 . . . 013

Table 3.1: Thermal Characteristics of Housing Envelope in Canada, 1997 . . . 022

Table 5.1: Machinery and Equipment Investments as a Share of Total Stock of Machinery and Equipment, 1992–1998 . . . 044

Table 5.2: Summary of Trends in Energy Use, Activity and Energy Intensity in the Industrial Sector, 1990–1998 . . . 048

Table 5.3: Activity Effect: Main Industries Responsible for the Variation in Activity, 1990–1998 . . . 049

Table 5.4: Variation in Energy Efficiency for Selected Industries,1990–1998 . . . 051

Table 6.1: Typical New Passenger Car Characteristics for 1970, 1990 and 1998 . . . 064

Table 6.2: Passenger Car and Truck Stocks Registered in Canada in 1990, 1995 and 1998 . . . 073

Table D.1: Reconciliation of Data on Energy Use Found in This Report with Statistics Canada's *Quarterly Report on Energy Supply Demand in Canada* Data (CANSIM), 1998 . . . 126

-X

Executive Summary

Throughout this report an energy barometer (a system of arrows) is used to depict the impact of the various factors on energy use. An arrow pointing upward indicates that this factor contributed to an increase in energy use. Alternatively an arrow pointing downward indicates that this factor contributed to a decrease in energy consumption. Arrows are described as follows.

The objective of this report is to improve our understanding of the contribution energy efficiency has made to limiting growth in secondary energy use and related greenhouse gas emissions in Canada between 1990 and 1998.

In December 1997, at the Third Conference of the Parties to the UNFCC, held in Kyoto, Japan, participating countries negotiated an international agreement on a timetable for greenhouse gas emission reductions. Canada's target is to reduce greenhouse gas emissions to 6 percent below 1990 levels by the 2008 to 2012 period. Improved energy efficiency has been and will continue to be a core element in Canada's response to the UNFCC, and will play a critical role in achieving the Kyoto target. Towards this end, this report by the Office of Energy Efficiency of Natural Resources Canada reviews secondary energy use trends and greenhouse gas emissions for five end-use sectors of the Canadian economy – the residential, commercial, industrial, transportation and agricultural sectors – from 1990 to 1998.

Greenhouse Gas Emissions

In 1998, secondary energy use accounted for about 70.5 percent of Canada's total energy requirements. Greenhouse gas emissions from secondary energy use, combined with emissions associated with the end use of electricity, are estimated to account for about 65.8 percent of all greenhouse gas emissions in Canada.

The Energy/Emissions Barometer – Secondary

From 1990 to 1998, secondary energy use in Canada increased by 9.2 percent, from 7018 petajoules to 7665 petajoules. Resulting greenhouse gas emissions increased by 10.4 percent. Growth in emissions was higher than growth in secondary energy use primarily because of a 1.1-percent increase in the greenhouse gas intensity of energy use. This increase reflects two key factors:

- shifts in the types of fuels consumed for end uses (i.e., increased use of natural gas and wood waste, mainly at the expense of oil products, which are more carbon intensive); and
- significant changes in the mix of fuels used to produce electricity (due to a decline in available nuclear and hydro power generation capacity[1] which was compensated for through use of coal and other high carbon fossil fuels.).

1 Nuclear generation capacity was affected by the shutdown of Ontario's Bruce power plant; reduced hydro power generation was due to low water level in reservoirs.

Secondary Energy Use

For the purposes of this report, growth in secondary energy use is considered to be influenced by changes in four main factors:

- activity levels in each sector;
- the structure of each sector (the mix of activity);
- weather; and
- energy efficiency.[2]

During the period under review, the 647-petajoule growth in secondary energy use was mostly influenced by growth in activity levels in each end-use sector. Had only the level of activity changed in each sector from 1990 to 1998, while structure, weather and energy efficiency remained at their 1990 levels, secondary energy use would have increased by 1080 petajoules.

Shifts in the structure of sectoral activity (e.g., shifts between industries or between commercial building types) contributed to a further increase of 215 petajoules in secondary energy use between 1990 and 1998. During this period, the distribution of sectoral activity shifted toward more energy-intensive activities and components of the Canadian economy.

On the other hand, changes in weather helped reduce secondary energy use during the review period, primarily in the residential and commercial sectors. The winter of 1998 was warmer than the winter of 1990, which meant that less energy was required for space heating. Without this change in weather, secondary energy use would have been 88 petajoules higher in 1998 than actual levels.

Energy efficiency improvements limited the growth in secondary energy use significantly. Had the level of energy efficiency not improved over the 1990 to 1998 period and only weather, structure and activity changed, secondary energy use would have been 430 petajoules higher in 1998 than the level actually consumed.

The OEE Energy Efficiency Index

To track these important changes in energy efficiency, the OEE has developed the OEE Energy Efficiency Index. The OEE Index tracks the changes in energy efficiency for five end-use sectors as a whole. As the figure below shows, by 1998 energy efficiency had improved by about 6 percent over 1990 levels. This translates into an average annual improvement of energy efficiency of 0.7 percent.

The OEE Energy Efficiency Index, 1990–1998 (index 1990 = 1.0)

End-Use Sector Highlights

The following sections of this chapter provide a brief review of trends in secondary energy use, greenhouse gas emissions, energy efficiency and other factors for each of the five end-use sectors that are discussed in this report.

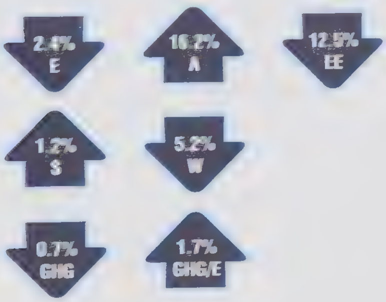
2 See page 7 for an explanation of the difference between energy efficiency and energy intensity.

Residential Sector

In 1998, the residential sector accounted for 16.8 percent of secondary energy use in Canada and 15.3 percent of emissions from total secondary energy use.

Between 1990 and 1998, residential energy use decreased by 2.4 percent, to 1288 petajoules, while resulting greenhouse gas emissions decreased by 0.7 percent. The reduction in emissions was less than the decline in energy use because of a 1.7-percent increase in the greenhouse gas intensity of residential energy use. This can be explained by a shift in the types of fuels used to generate electricity, with growth in the use of high-carbon fossil fuels and declines in the available nuclear power generating capacity and hydroelectricity.

The Energy/Emissions Barometer – Residential



The change in residential energy use was largely the result of a 16.2-percent growth in activity, as measured by the number of households in Canada and the total floor area of all dwellings. Had only activity changed in the review period, and all other factors remained at 1990 levels, secondary energy use in the residential sector would have increased by 214 petajoules.

Changes in weather helped limit the increase in residential sector energy use over the 1990 to 1998 period. As a result of a warmer winter in 1998, there was a decline of 68 petajoules in space heating requirements compared to 1990. Energy demand for space cooling increased marginally because of a warmer summer in 1998. As well, changes in structure (the percentage of energy used for different end-uses) increased energy consumption by 16 petajoules.

Energy efficiency improvements also helped to limit the growth in residential energy use. Had only energy efficiency changed in the review period, residential energy use would have decreased by 165 petajoules.

Commercial Sector

In 1998, commercial energy use accounted for 12.3 percent of secondary energy use in Canada and 11.9 percent of emissions from total secondary energy use.

Between 1990 and 1998, commercial energy use, including street lighting, increased by 8.9 percent, from 867 to 944 petajoules. Excluding street lighting, energy use increased by 9.1 percent, from 858 to 936. Greenhouse gas emissions from the sector increased by 13.1 percent. The greenhouse gas intensity of commercial energy use increased by 3.9 percent during the review period. As was the case in the residential sector, this increase was due largely to a shift in the electricity generation fuel mix.

The Energy/Emissions Barometer – Commercial

The reported change in commercial energy use was largely due to a growth in activity (measured as growth in floor space), which increased by 13.8 percent between 1990 and 1998. Had only activity changed, and all other factors remained at 1990 levels, secondary energy

use would have increased by 118 petajoules, rather than the actual 77 petajoules. Changes in structure increased energy use by a further 3 petajoules.

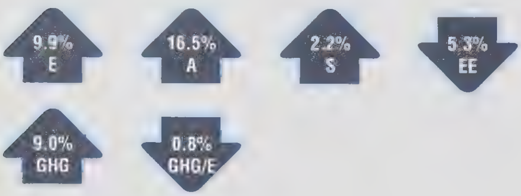
Warmer winter weather in 1998 compared to 1990 reduced space heating requirements in the commercial sector, resulting in a 20-petajoule decrease in energy use. As well, aggregate energy intensity decreased by 4.3 percent and energy efficiency improved by 2.1 percent during the review period. This improvement in the energy efficiency effect was responsible for a 18-petajoule decline in commercial sector energy use.

Industrial Sector

In 1998, industrial energy use accounted for 39.5 percent of secondary energy use in Canada and 34.4 percent of greenhouse gas emissions from total secondary energy use.

Between 1990 and 1998, industrial energy use increased by 9.9 percent, to 3027 petajoules, while resulting greenhouse gas emissions increased by 9.0 percent. The greenhouse gas intensity of industrial energy use declined by 0.8 percent. However, if emissions related to electricity end-use were not included, greenhouse gas intensity would have declined by 5.1 percent.

The Energy/Emissions Barometer – Industrial



The change in industrial energy use was largely the result of growth in activity (measured as real gross domestic product and physical units of production), which increased by 16.5 percent between 1990 and 1998. Had all factors remained at 1990 levels, and only activity changed, industrial energy use would have increased by 455 petajoules, rather than the actual 272 petajoules. Changes in structure (a shift toward more energy-intensive industries) also contributed to an increase in energy use of 62 petajoules.

Energy efficiency improved by 5.3 percent between 1990 and 1998. Had only energy efficiency changed over the period, while activity and structure remained the same, industrial energy use would have been 145 petajoules lower in 1998 than actual levels.

On an industry-by-industry basis, there were notable improvements in energy efficiency in the electrical and electronic products (55 percent), glass and glass products (49 percent), beverage (excluding brewery) (37 percent), rubber products (42 percent), brewery (22 percent) and primary textile (23 percent). Some of the structural factors that contributed to these improvements include replacement of older, less efficient equipment, rationalization of industries, changes in industrial processes, and a number of aggressive programs to improve energy efficiency and reduce energy consumption.

Transportation Sector

In 1998, transportation energy use accounted for 28.5 percent of secondary energy use in Canada and 34.8 percent of greenhouse gas emissions from total secondary energy use.

Between 1990 and 1998, transportation energy use increased by 16.2 percent, to 2182 petajoules. The increase in resulting emissions was similar.

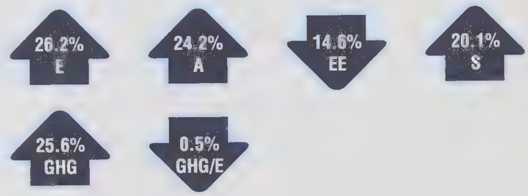
The Energy/Emissions Barometer – Passenger Transportation

Energy use for passenger transportation, which accounts for 58.9 percent of total transportation energy use, increased by 9.9 percent between 1990 and 1998. This change is mainly the result of an 11.9-percent increase in activity (measured as passenger-kilometres). Had all factors except activity remained at their 1990 levels, passenger transportation energy use would have increased by 134 petajoules. A shift in consumer preferences toward light trucks also contributed to increased energy intensity. In 1998, 25.9 percent of passenger light vehicles in Canada were light trucks, compared to 16.1 percent in 1990. Changes in structure resulted in a 2-petajoule increase in passenger transportation energy use. Had only energy efficiency changed over the period, energy use for passenger transportation would have decreased by 7 petajoules.

The amount of energy used to move passengers by rail dropped by 56.9 percent between 1990 and 1998. This was due to reductions in both activity (resulting in a decline in energy use of 1 petajoule) and energy efficiency (resulting in a decline of 2 petajoules). Aviation travel accounted for 17.2 percent (221 petajoules) of passenger transportation energy use in 1998. Aviation was the only passenger transportation mode to increase its share of energy use between 1990 and 1998.

Energy used to move freight increased by 26.2 percent between 1990 and 1998, largely as a result of a 24.2-percent increase in activity (measured as tonne-kilometres). Had all factors except activity remained at their 1990 levels, freight transportation energy use would have increased by 159 petajoules. The effect of structural shifts, away from marine toward trucks, contributed to an increase in energy use of only 132 petajoules.

The Energy/Emissions Barometer – Freight Transportation



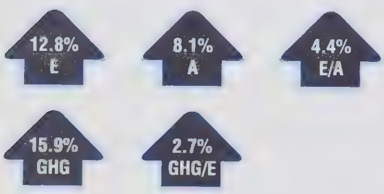
Energy efficiency improved by 14.6 percent in the freight transportation sub-sector between 1990 and 1998. Had energy efficiency not improved, freight transportation energy use would have been 96 petajoules higher in 1998 than actual levels.

Agriculture Sector

In 1998, the agricultural sector accounted for 2.9 percent of secondary energy use in Canada and 3.5 percent of emissions from total secondary energy use.

Between 1990 and 1998, agricultural energy use increased by 12.8 percent, to 225 petajoules, while resulting greenhouse gas emissions increased by 15.9 percent. The discrepancy in growth in emissions and growth in energy use is mainly a result of a 2.7-percent increase in the greenhouse gas intensity of agricultural energy use.

The Energy/Emissions Barometer – Agriculture



The change in agricultural energy use was largely due to growth in activity (measured as real gross domestic product), which increased by 8.1 percent between 1990 and 1998. Had only activity changed over the review period, 1998 energy use would have been 215 petajoules, rather than 225. Alternatively, had only aggregate energy intensity changed, 1998 energy use would have been 208 petajoules instead of 225.

Scope of the Report

Improved energy efficiency is a cornerstone of Canada's National Action Program on Climate Change...

This report provides an overview of trends in energy efficiency, energy use and associated greenhouse gas emissions, between 1990 and 1998, in the five major energy-using sectors of the Canadian economy – the residential, commercial, industrial, transportation and agriculture sectors.

Background – Canada's Emissions Reductions Targets and Reporting Practices

In December 1997, at the Third Conference of the Parties to the United Nations Framework Convention on Climate Change in Kyoto, Japan, participating countries agreed to a timetable of greenhouse gas emissions reductions for the period between 2008 to 2012. Canada's target under this international agreement – the Kyoto Protocol – is to reduce emissions to 6 percent below 1990 levels. By comparison, the European Union committed to reduce emissions by 8 percent, the United States by 7 percent and Japan by 6 percent. For the 38 industrialized countries that negotiated the Kyoto Protocol, the average reduction target is 5.2 percent.

Most countries plan to meet their emissions reduction objectives in part by improving energy efficiency across the economy. In Canada, for several years governments at all levels have been delivering programs to improve public awareness of the benefits of energy efficiency, to reduce market barriers to energy efficiency, and to accelerate the development and deployment of more energy-efficient technologies. Improved energy efficiency is a cornerstone of Canada's National Action Program on Climate Change (NAPCC), a federal-provincial strategy for achieving emissions reductions.

About This Report

The NAPCC includes a commitment to develop indicators of progress in energy efficiency.[1] The current document is the fifth report on such indicators, and continues to deliver on Canada's commitment to track trends in energy efficiency and energy use and to understand their impact on changes in greenhouse gas emissions.[2] More specifically, the objectives of this report are as follows:

- identify and measure the different factors influencing energy use and greenhouse gas emissions in Canada; and
- explain how changes in energy efficiency contribute to secondary energy use and greenhouse gas emissions.

As in previous reports, a special analytical technique (the factorization method, described in more detail in Appendix C) is used to assess the impact of different factors influencing trends in energy use and greenhouse gas emissions. It is important to note at the outset of this report that the quality and quantity of data upon which the analysis is based (Appendix A provides a complete list of data sources) vary greatly from sector to sector. The Office of Energy Efficiency continues to improve the quality of the information used in its analysis, and this report reflects specific data and methodology enhancements since publication of the previous report:

- Emissions of nitrous oxide (N_2O) and methane (CH_4) related to secondary energy use have been calculated and are included in this report. All greenhouse gas emissions are reported in terms of CO_2 equivalent.
- The analysis for the industrial sector is now based on a breakdown of 40 industries, compared to 39 in the previous report.
- The OEE Energy Efficiency Index (see page 4) reports on improvements in energy efficiency rather than the effects of energy efficiency on energy use.

1 Government of Canada, *Canada's National Action Program on Climate Change*, Ottawa, Ontario, 1995, Chapter 5.

2 The first report, *Energy Efficiency Trends in Canada*, was published in April 1996.

- Activity levels in the residential sector are now measured using the number of Canadian households and the floor area of dwellings (previously, the number of households was the only variable used to measure activity).

The remainder of this chapter provides information on the relationship between energy efficiency, secondary energy use and greenhouse gas emissions and briefly discusses the approach and data used to model these relationships. Chapter 2 provides a discussion of secondary energy use, energy efficiency and greenhouse gas emissions trends for the entire economy, followed by a sector-by-sector analysis in subsequent chapters. Additional details on types of indicators, data sources, the factorization method, etc., are provided in appendices to the main report.

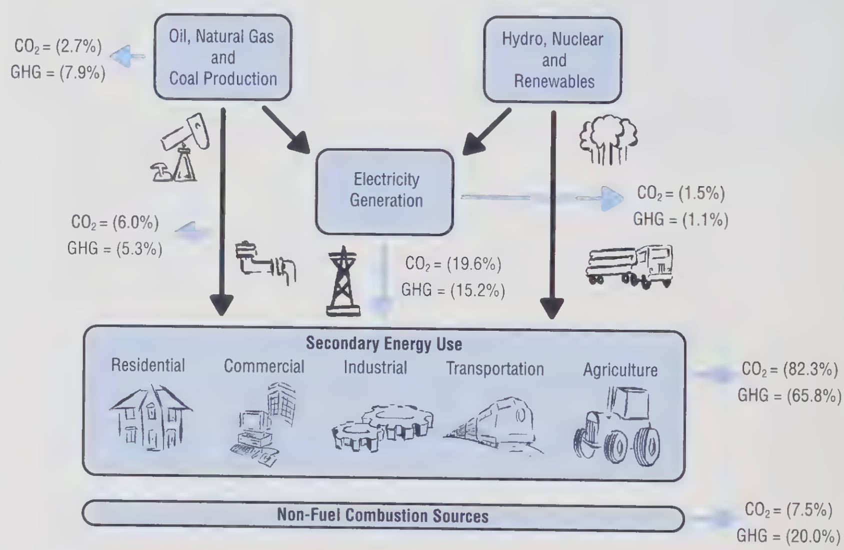
1.1 The Relationship Between Secondary Energy Use and Greenhouse Gas Emissions

This report deals primarily with secondary energy use and the resulting greenhouse gas emissions. With the exception of electricity, it does not examine the emissions from the production of energy other than the mining and refining component (e.g. natural gas pipeline leakage is not included). All emissions associated with changes in electricity end-use arise during generation. The emissions reported in this document include emissions from electricity end-use.[3]

The relationship between secondary energy use and greenhouse gas emissions is illustrated in Figure 1.1. Greenhouse gas emissions originate from the combustion of secondary energy, from non-combustion uses of energy (industrial processes), from electricity generation and from oil and gas production. At the secondary level, most energy is used in the five sectors addressed in this report to meet specific end-uses, such as space heating. The volume of greenhouse gas emissions from secondary energy use varies according to the quantity and type of fuel used.

In 1998, total greenhouse gas emissions from all energy sources (primary and secondary energy use) in Canada were estimated to be 686 megatonnes. Of this amount, 451 megatonnes, or 65.8 percent of the total, were a result of energy use at the secondary or end-use level. This decreases to 346 megatonnes, or 50.4 percent of total Canadian greenhouse gas emissions, when emissions related to electricity end-use are excluded.[4]

Figure 1.1: The Relationship Between Secondary Energy Use and Greenhouse Gas Emissions



Note: This report uses a variety of indicator types to explain the role of energy efficiency in the evolution of secondary energy use and emissions. For more details on indicators, see Appendix B.

3 All greenhouse gas emissions associated with electricity end-use are created during the production of electricity. For the purposes of this report, end-use electricity has been attributed a greenhouse gas emissions factor that reflects the average mix of fuels used to generate electricity in Canada.

4 From this point forward in this report, any reference to greenhouse gas emissions implies emissions from secondary energy use, including emissions related to electricity end-use.

1.2 Structure of the Analysis

In subsequent chapters of this report, the OEE's analysis deals with the following:

- first, the current status (1998 data) of energy use, energy efficiency and greenhouse gas emissions;
- second, trends in energy use and energy efficiency between 1990 (the baseline year for the United Nations Framework Convention on Climate Change) and 1998; and
- third, trends in greenhouse gas emissions between 1990 and 1998.

Description of Energy Use and Emissions

This section of each chapter is intended to provide a snapshot of total secondary energy use and related greenhouse gas emissions in 1998.

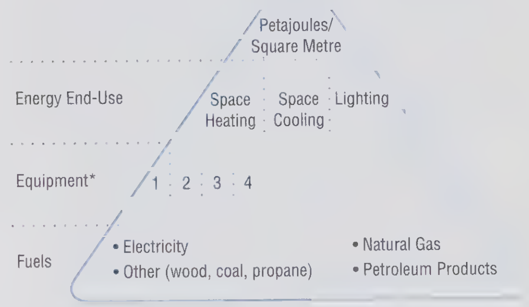
In Chapter 2, the snapshot is provided for the economy as a whole. Chapters 3 to 7 address the individual end-use sectors, providing information on total secondary energy use and total greenhouse gas emissions for the sector in 1998. Other relevant information, such as the most common end-uses of energy in each sector, the most common fuels used, etc., may also be provided.

Analysis of Trends in Energy Use and Efficiency

The main objective of this report is to identify trends in energy efficiency and to relate them to trends in aggregate energy use and, ultimately, to trends in greenhouse gas emissions. To support this complex analysis, the OEE has developed "pyramids" for each sector to establish a relationship between various indicators of energy use (a discussion of types of indicators is provided in Appendix B).

Figure 1.2 shows one of the indicator pyramids for the residential sector. The pyramid presents energy use at increasing levels of detail, from its most aggregate level (total residential energy use) at the top of the pyramid to a disaggregated level (energy use by equipment type) at the base. Indicator pyramids for other sectors are presented in Appendix C.

Figure 1.2: Residential Sector Floor Space Services Indicator Pyramid



*Equipment examples include:
Space heating – normal, mid- and high-efficiency furnaces, electric baseboard heaters, heat pumps, coal, wood & propane furnaces dual systems
Space cooling – room air conditioners and central air conditioners

While the pyramid approach provides a structure for indicators of energy use, it does not explain how changes in one indicator contribute to changes in another. For this level of analysis, the OEE uses a factorization method to attribute the change in energy use at any level of the pyramid to four factors: changes in activity, structure, weather and energy efficiency relative to the base year (definitions of activity and structure for each sector are provided in Table 1.2).

For example, in the case of the residential sector, the factorization analysis would attribute changes in total residential energy use to a combination of

- growth or decline in activity (number of households and/or total floor area);
- changes in structure (the types of energy used for various end-uses, such as space heating or lighting);
- changes in weather (e.g., warmer or colder summer or winter relative to the base year); and
- changes in energy efficiency for each end-use (e.g., the use of more efficient appliances or heating equipment).

Using this factorization method, if all other factors remained constant,

- an increase in sector activity would lead to increased energy use and greenhouse gas emissions from that sector (and vice versa);
- a shift in the structure of activity toward more energy-intensive types of activity would lead to increased energy use and greenhouse gas emissions from that sector (and vice versa);
- changes in weather could lead to either increases or decreases in energy use and greenhouse gas emissions (i.e., a colder winter or warmer summer can both lead to increased energy use, for space heating and space cooling, respectively); and
- improvements in energy efficiency would result in a decrease in energy use and greenhouse gas emissions (and vice versa).

For the purpose of this report, changes in energy efficiency (activity per unit of energy use) are approximated by changes in energy intensity (energy by activity) adjusted for structure, activity and weather. Changes in energy efficiency are calculated at several levels. For instance, in the case of the industrial sector, changes in energy efficiency are calculated at the industry level, the sector level and at the secondary level (i.e., the all five sectors together).

It should be noted that estimates of energy efficiency in this report reflect factors other than "technical energy efficiency." Pure or technical energy efficiency can only be measured at the "micro" level (e.g., the energy efficiency of a refrigerator or a furnace). While the indicator pyramids for each sector permit significant levels of analysis, even the most disaggregated energy efficiencies presented in this report may reflect factors beyond technical energy efficiency. In the industrial sector, for example, the most disaggregated energy efficiency presented here is an industry-specific efficiency that reflects a combination of technical energy efficiency and shifts in the mix of products, processes and/or fuels for that industry.

Table 1.2: Definitions of Activity and Structure Used in This Report, by Sector

Sector	Activity	Structure
Residential	Number of households and floor area of houses (space conditioning)	End-use mix: (e.g., space heating, space cooling, appliances, lighting and water heating)
Commercial	Floor space	Building type (e.g., offices, retail stores and hotels/restaurants)
Industrial	Gross domestic product and, where available, physical units of output (e.g., tonnes, litres)	Sector mix: (e.g., pulp and paper, other manufacturing, iron and steel)
Transportation	Passenger-kilometres and tonne-kilometres	Mode mix: (e.g., road, rail, air and marine)
Agriculture	Gross domestic product	n.a.

Changes in energy efficiency are estimated for all five end-use sectors using the approach described above (these estimates are presented in Chapters 3 to 7). Variations in sectoral energy efficiency are aggregated into a single index of secondary energy efficiency, called the OEE Energy Efficiency Index. This index, presented in Figure 1.3, shows an increase in value, which indicates an improvement in secondary energy efficiency of about 0.7 percent per year between 1990 and 1998.

Figure 1.3: The OEE Energy Efficiency Index, 1990–1998 (index 1990 = 1.0)

... an improvement in secondary energy efficiency of about 0.7 percent per year between 1990 and 1998.

The OEE Energy Efficiency Index provides a much better estimation of changes in energy efficiency than the more commonly used ratio of gross domestic product (GDP) per unit of secondary energy use. This latter ratio captures not only the impact of changes in energy efficiency on energy consumption but also changes in activity, structure and weather.

Work continues to improve both the quality and the availability of energy data to ensure that the OEE Energy Efficiency Index continues to improve as an energy efficiency indicator.

Analysis of Trends in Greenhouse Gas Emissions

Chapter 2 provides an analysis of greenhouse gas emissions trends across the economy – in other words, the sum of emissions arising from energy use in all five end-use sectors. Chapters 3 to 7 analyse emissions trends on a sector-by-sector basis. In each sector, emissions are the product of two related factors: total energy use, and the greenhouse gas intensity of this energy use. Chapters 3 to 7 elaborate on the principal factors underlying growth in both energy use and the greenhouse gas intensity of energy use,[5] thereby documenting the two forces driving growth in energy-related greenhouse gas emissions.

1.3 The Data

Good quality data on energy use, greenhouse gas emissions and activity levels in each end-use sector is crucial to the quality of the OEE's trends analysis. The strengths and weaknesses of the major data used in this report are discussed below, along with some data improvements that have been introduced since the previous report. Detailed sources and definitions of the data used in this report are provided in Appendices A and D.

Activity

In the *residential* sector, activity is measured by the number of households in Canada and the total floor area of these dwellings.

In the *agricultural* sector, activity is measured by the total agricultural gross domestic product.

In the *industrial* sector, for industries with a homogeneous product, activity is measured by physical units of production. This information is compiled by the Canadian Industrial Energy End-Use Data and Analysis Centre (CIEEDAC) in support of the Canadian Industry Program for Energy Conservation (CIPEC).[6] For industries with heterogeneous products (i.e., the products are too diverse to allow the choice of a single unit of physical production), GDP data from Statistics Canada are used as the measure of activity. It is generally recognized that physical units of production are a better measure of activity when tracking energy efficiency improvements at the sectoral level. However, both measures are well aligned with energy use.

In the *commercial* sector, the measure of activity is floor space, but little actual data exist on commercial floor area in Canada. For the purposes of this report, floor space is estimated based on investment flows, demolition rates, capital expenditures by structure and asset type and average construction cost data.

In the *transportation* sector, which consists of both passenger and freight transportation, there are also data limitations. For the passenger transportation sub-sector, activity is defined in terms of passenger-kilometres, while freight activity is defined using tonne-kilometres. Unfortunately, only partial data are available for either of these measures. Passenger-kilometre data for air and rail travel are available from Statistics Canada. However, passenger-kilometre travel via light-

5 The greenhouse gas intensity of energy use is a weighted average of fuel-specific greenhouse gas intensities. The weights used to calculate the intensity for a given sector are based on each fuel's share of energy demand in that sector. In this report, analyses of changes in the greenhouse gas intensity of energy use in each sector will focus on shifts in the fuel mix for that sector.

6 Canadian Industrial Energy End-Use Data and Analysis Centre, Simon Fraser University, *Energy Intensity Indicators for Canadian Industry, 1990–1998*, British Columbia.

duty vehicles and buses must be estimated from data on vehicle and bus stocks, average distances travelled and vehicle occupancy rates. These data are only available for certain years, so time series estimates have been developed for missing years. For freight transportation, Transport Canada provides tonne-kilometre data for marine freight activity, and Statistics Canada provides data for rail activity and partial data for trucking activity.

Energy Use

Aggregate energy use data for each sector are extracted from Statistics Canada's *Quarterly Report on Energy Supply-Demand in Canada* (QRESD), Canada's official energy balance. These data are available by fuel type for each major end-use sector. Energy use data throughout this report are presented in petajoules. One petajoule is equivalent to the energy requirement of about 10 000 houses in a year.

In the *industrial* sector, the QRESD data are supplemented by CIEEDAC's detailed energy use database to provide a breakdown of energy use in 40 industries (the QRESD data are broken down by 10 industries). This has allowed more precise identification of structural changes arising from industry composition and has contributed greatly to an improved understanding of the factors underlying industrial energy use.

In the *residential* sector, energy demand estimates for each end-use are derived through a calibration process that takes into account aggregate energy use and detailed data on the characteristics of buildings and household equipment.

A modelling approach is also used in the *commercial* sector to estimate end-use demand by building type. These end-use estimates are arrived at normatively through discussions with sector experts. Among the five end-use sectors, energy use data limitations are most significant for the commercial sector.

In the *transportation* sector, aggregate energy demand data for the road, rail, aviation and marine modes of transportation are available from the QRESD. A model is then used to split energy demand into passenger and freight transportation.

In the *agricultural* sector, the QRESD supplies aggregate energy demand data by fuel type. A model is then used to re-group the energy use into motive and non-motive energy demand.

Greenhouse Gas Emissions

The greenhouse gas emissions data in this report are derived by multiplying secondary energy use by emission factors developed by Environment Canada.[7] Environment Canada provides emissions factors on a physical unit base, and the OEE converts them to petajoules. For the first time, this report includes data on nitrous oxide (N_2O) and methane (CH_4) emissions. Both N_2O and CH_4 emissions have been converted to carbon dioxide (CO_2) equivalents using their internationally recognized 100-year global warming potentials of 310 and 21, respectively.[8]

The sector-specific emissions reported here differ from those presented by Environment Canada. This is primarily due to differences in the sectoral definitions used by the OEE and Environment Canada (i.e., the QRESD energy data may be reallocated from one category to another by either or both organizations).[9] As well, Environment Canada's estimates of wood fuel consumption in the residential sector exceed the OEE's estimates quoted in this report. (At the time of writing, Environment Canada had not incorporated the latest Statistics Canada revisions to the QRESD).

Aggregate energy use data for each sector are extracted from Statistics Canada's Quarterly Report on Energy Supply-Demand in Canada (QRESD), Canada's official energy balance.

7 Environment Canada, *Canada's Greenhouse Gas Inventory: 1997 Emissions and Removals with Trends*, Ottawa, Ontario, April 1999.

8 Ibid.

9 Differences in the allocation of greenhouse gas emissions by the OEE and Environment Canada are documented in Appendix E.

1.4 Overview of the Report

Chapter 2 reviews aggregate trends in secondary energy use and emissions from 1990 to 1998 and provides an overview of the contribution of sectoral trends to these aggregate trends.

Chapters 3 to 7 provide an in-depth analysis of the trends in energy use and emissions for each of the five end-use sectors. The analysis of energy use attributes to activity, structure, weather and energy efficiency a share in the change in energy demand.

Appendix A presents the data and sources used to prepare the graphs in the report.

Appendix B presents the indicators of energy use used in each of the sectors.

Appendix C presents the methodology and data sources that underlie the factorization of energy use.

Appendices D and E present a reconciliation of the sectoral definitions used in this report with those found in Statistics Canada's QRESD and Environment Canada's *Greenhouse Gas Inventory: 1997 Emissions and Removals with Trends*.

Appendix F presents the analytical framework for examining greenhouse gas emissions trends, and Appendix G defines the technical terms used in the report.

This report describes only part of the data and indicators collated for the analysis. All of the data prepared for this report are available on the Internet at:

http://oee.nrcan.gc.ca/general/trends/index_e.htm.

Energy Efficiency vs. Energy Intensity

Traditionally energy intensity has referred to the ratio of the total amount of *energy* used by an entity (e.g. refrigerator, house, industry, economy, etc.) over the total amount of *activity* (e.g. tonnes of steel, floor space, kilometres travelled per passenger) that the entity engaged in over a specified time period. In this report this is referred to as aggregate energy intensity and it is the total energy consumed by a sector divided by the total amount of activity in that sector over a one-year period.

On the other hand, energy efficiency refers specifically to how much *activity* a specific technology can generate for a given amount of *energy* over a certain amount of time. When referring to technologies, the distinction between energy efficiency and energy intensity is insignificant – one is simply the inverse of the other. However, energy efficiency and intensity begin to diverge as the system you are referring to becomes more complex. For instance, if the weather becomes cooler, the energy efficiency of the heating systems in the entire residential sector might not change but the energy intensity of that home or the residential sector would increase as it would require more total energy to provide the same amount of activity.

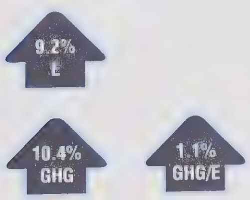
The analysis in this report does not attempt to measure energy efficiency directly. To do so one would be required to measure the energy efficiency of every piece of equipment in every sector of the economy. What is measured instead are the changes in the ratio of the level of activity each end-use sector engages in to the energy that that sector consumes over a one-year period, net of the impact of changes in the weather and the structure of the economy. It approximates the change in the average energy efficiency of the equipment in each end-use sector.

Economy-Wide Trends in End-Use Energy, Energy Efficiency and Greenhouse Gas Emissions

Highlights

- From 1990 to 1998, secondary energy use across the Canadian economy increased by 9.2 percent, for a total of 7665 petajoules in 1998. This growth was the result of several factors:
  - Activity increased in all five major energy using sectors, which in turn caused energy use in all sectors except residential to increase. Had activity levels not increased between 1990 and 1998, secondary energy use in Canada would have been 1080 petajoules lower in 1998 than actual consumption.
  - Changes in the mix of activity toward more energy-intensive activities also contributed to increased energy use. Had the mix of activity not changed between 1990 and 1998, secondary energy use in Canada would have been 215 petajoules lower in 1998 than actual consumption.
  - Warmer weather in 1998 compared to 1990 helped offset the increase in energy use noted above (i.e., warmer weather in 1998 meant less energy was used for space heating). Had the weather been the same in 1998 as in 1990, secondary energy use in Canada would have been 88 petajoules higher in 1998 than actual consumption.
  - Changes in energy efficiency also mitigated the increase in secondary energy use between 1990 and 1998. Had all other factors remained constant over the period, and only energy efficiency changed, secondary energy use in Canada would have increased by 430 petajoules from the 1990 level.
- Greenhouse gas emissions from secondary energy use increased by 43 megatonnes, or 10.4 percent, between 1990 and 1998.
- The greenhouse gas intensity of secondary energy use increased by 1.1 percent from 1990 to 1998, mainly due to a shift toward fuels with a higher greenhouse gas content. Had this fuel shift not occurred, greenhouse gas emissions would have been 6.6 megatonnes of CO_2 equivalent,[1] lower in 1998 than actual levels.

The Energy/Emissions Barometer – All Sectors



2.1 Overview – Energy Use and Greenhouse Gas Emissions

In 1998, secondary energy use accounted for 70.5 percent of Canada's total energy requirements. At the secondary level, energy is used in five sectors: residential, commercial, industrial, transportation and agriculture. The industrial sector accounted for the largest share of secondary energy use (39 percent) in 1998,[2] followed by the transportation sector (28 percent), the residential sector (17 percent), the commercial sector (12 percent) and the agriculture sector (close to 3 percent).

Table 2.1 illustrates energy use and associated greenhouse gas emissions, by sector, in 1998. The transportation and industrial sectors account for the largest shares of greenhouse gas emissions from secondary energy use. Transportation is 34.8 percent, industrial is 34.4 percent, followed by the residential (15 percent), commercial (12 percent) and agriculture sectors (more than 3 percent). Emissions from the transportation and agriculture sectors exceed their share of energy consumption because these sectors tend to use forms of energy that are more greenhouse gas intensive.

Table 2.1: Sectoral Energy Distribution and Associated Greenhouse Gas Emissions, 1998

Sectors	Energy (petajoules)	Greenhouse Gas Emissions (megatonnes)
Residential	1288	69.3
Commercial	944	53.8
Industrial	3027	155
Transportation	2182	157
Passenger	1285	92
Freight	828	60
Off-Road	69	5
Agriculture	225	16
Total	7665	451

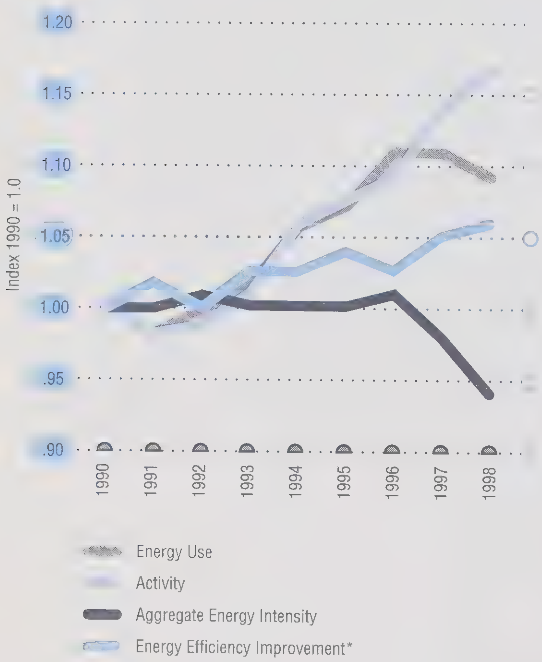
1 The share of carbon dioxide emissions in greenhouse gas emissions was 97 percent in both 1990 and 1998.

2 The definition of energy use for each sector (for the purposes of this report) is documented in Appendix D. These definitions are different from the sectoral definitions used by Environment Canada in *Canada's Greenhouse Gas Inventory: 1997 Emissions and Removals with Trends.*

2.2 Trends in Energy Use and Greenhouse Gas Emissions

Figure 2.1 illustrates the trends in secondary energy use, activity, aggregate energy intensity and energy efficiency (the OEE Energy Efficiency Index described in Chapter 1) from 1990 to 1998. Secondary energy use increased by 9.2 percent from 1990 to 1998 while aggregate activity (GDP) increased by 16.6 percent. Aggregate energy intensity (E/GDP) decreased by 6.3 percent while the energy efficiency improved by 6.0 percent.

Figure 2.1: Secondary Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 (index 1990 = 1.0)



*This report presents an index of energy efficiency improvements while previous reports presented an index of the effects of energy efficiency on energy use.

Table 2.2 provides an overview of sectoral activity growth and the corresponding growth in secondary energy use and greenhouse gas emissions between 1990 and 1998. As illustrated, activity growth was most significant in the freight transportation sector, which reported an increase of almost 24.2 percent. Differences between growth in a sector's activity and growth in its energy use are due to the influence of other factors (energy efficiency improvements, changes in weather and changes in structure, or the mix of activity within a sector). These factors are discussed in detail, sector by sector, in the corresponding chapters.

Table 2.2: Sectoral Activity, Energy Use and Greenhouse Gas Emissions Growth, 1990–1998 (percent)

Sectors	Activity	Energy Use	Greenhouse Gas Emissions
Residential	17.2	-2.4	-0.8
Commercial	13.8	8.9	13.1
Industrial	14.7*	9.9	9.0
Transportation		16.2	16.2
Passenger	11.9	9.9	10.2
Freight	24.2	26.2	25.6
Agriculture	8.1	12.8	15.9

* represents gross domestic product only.

Secondary energy demand grew by 9.2 percent between 1990 and 1998, from 7018 petajoules to 7665 petajoules. Energy use decreased by 2.4 percent in the residential sector but increased in all other end-use sectors. The largest percentage increase was recorded in the transportation sector (16.2 percent), followed by the agriculture sector (12.8 percent), the industrial sector (9.9 percent) and the commercial sector (8.9 percent).

Corresponding with the above-noted increases, greenhouse gas emissions from secondary energy use increased by a total of 10.4 percent, from 409 megatonnes in 1990 to 451 megatonnes in 1998. The largest change occurred in the transportation sector, where emissions grew by more than 16 percent over the

Secondary energy use increased by 9.2 percent from 1990 to 1998 while aggregate activity (GDP) increased by 16.6 percent.

review period. Agriculture sector emissions also increased significantly over the period (15.9 percent), followed by the commercial sector (13.1 percent), and industrial sector (9.0 percent). Residential sector emissions declined by 0.8 percent.

The carbon dioxide intensity of electricity increased from 55.6 tonnes per terajoule in 1990 to 61.3 tonnes per terajoule in 1998.

As noted in Chapter 1, the OEE's analysis of emissions trends encompasses three greenhouse gases – CO_2, CH_4 and N_2O. Table 2.3 shows the proportion of CO_2 in the total greenhouse gas emissions for each sector. As noted in the table, carbon dioxide's proportion of emissions is lower in the residential, transportation and agriculture sectors (where CH_4 and N_2O make a larger contribution to emissions) than in the commercial and industrial sectors. This particularity will be discussed in the residential, transportation and agriculture chapters.

Table 2.3: Share of Carbon Dioxide in Total Greenhouse Gas Emissions, by Sector, 1990 and 1998

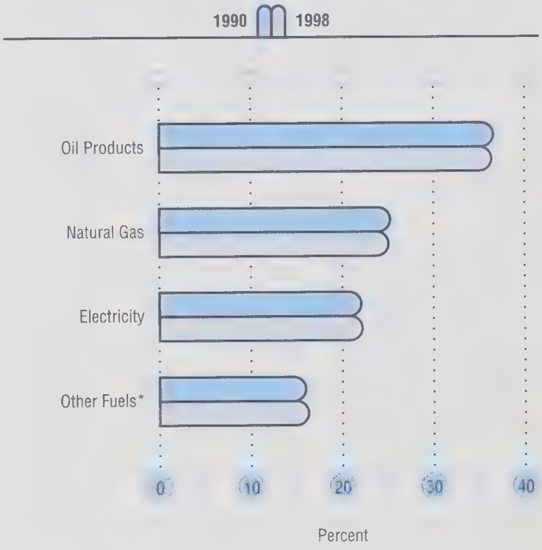
Sectors	1990	1998
Residential	96.5	96.7
Agriculture	94.3	93.5
Commercial	99.5	99.5
Transportation	95.8	95.9
Industrial	98.1	98.1

The OEE's analysis of trends in greenhouse gas emissions includes emissions related to electricity end-use.[3] During the review period, changes in the mix of fuels used to generate electricity increased the overall carbon dioxide intensity of secondary energy use, which in turn applied additional upward pressure on the growth in emissions. Specifically, the carbon dioxide intensity of electricity increased from 55.6 tonnes per terajoule in 1990 to 61.3 tonnes per terajoule in 1998 (about 25 percent more carbon intensive than natural gas in 1998). This was the result of the following:

- a significant decline in the percentage of electricity generated from nuclear power and hydroelectricity (due to reactor shut-downs and lower water levels in some areas, respectively). Neither of these fuels produces greenhouse gas emissions; and
- a consequential increase in the use of carbon-intensive fossil fuels, which include coal to generate electricity. From 1990 to 1998, electricity generation from fossil fuels[4] increased by 12.4 percent; for coal, the increase was 30.7 percent.

Were emissions related to electricity generation not included in the analysis, greenhouse gas emissions from secondary energy use in Canada would have increased by about 24 megatonnes, or 7.6 percent, between 1990 and 1998 (from 322 megatonnes of CO_2 equivalent in 1990 to 346 megatonnes of CO_2 equivalent in 1998).

Figure 2.2: Secondary Energy Fuel Shares, 1990 and 1998 (percent)



* liquefied petroleum gases, coal, coke & coke oven gases, steam, biomass

3 Electricity end-use consumption is attributed to an emissions factor that reflects the average mix of fuels used to generate electricity in Canada.

4 Coal, natural gas, diesel fuel oil, light fuel oil, heavy fuel oil, wood and spent pulping liquor are fossil fuels.

Greenhouse gas emissions are affected by two principal factors: the amount of energy used to perform an activity, and the fuel mix (which determines the greenhouse gas intensity per unit of energy). Figure 2.2 shows secondary energy fuel shares for the review period. From 1990 to 1998, electricity increased its share by 0.2 percentage point while oil products decreased by 0.2 percentage point. During the same period, other fuels (mostly wood waste and pulping liquor used in the pulp and paper sector) increased their share by 0.3 percentage point while natural gas decreased by 0.2 percentage point.

Since the greenhouse gas intensity of electricity is lower than most oil products, this fuel switching helped mitigate the increase in greenhouse gas emissions between 1990 and 1998. On the other hand, wood waste greenhouse gas intensity is significantly lower than that of natural gas. This shift also helped mitigate the increase in greenhouse gas emissions.

Table 2.4 shows the impact of changes in activity, structure, weather and energy efficiency on the growth in secondary energy use between 1990 and 1998. A fifth factor, the interaction effect, is also illustrated in Table 2.4. This factor results from the interaction between the four other factors and is explained in detail in Appendix C ("Note on Interaction Terms").

Table 2.4 reveals that growth in sectoral activity was the single most important factor influencing growth in secondary energy use during the review period. Had only the level of activity changed in each sector, while structure, weather and energy intensity remained at their 1990 levels, secondary energy use would have increased by 1080 petajoules in 1998, rather than the actual 647 petajoules.

Growth in sectoral activity was the single most important factor influencing growth in secondary energy use during the review period.

Table 2.4: Factors Influencing Growth in Secondary Energy Use, 1990–1998 (petajoules)

Sector	Energy Use 1990	1998	1998 less, '90 [5]	A	S	W	EE	I	Other
Residential	1319	1288	-32	213.8	16.3	-68.1	-164.6	-29.2	NA
Commercial [1]	867	944	77	118.2	2.9	-19.6	-17.8	-5.6	-1.3
Industrial	2755	3027	272	455.1	61.8	NA	-144.7	-99.9	NA
Transportation	1878	2182	304	292.7	133.7	NA	-103.1	-26.7	7.5
Passenger [2]	1169	1285	116	134.2	1.9	NA	-7.3	-4.1	-8.8
Freight	656	828	172	158.5	131.8	NA	-95.8	-22.7	0.0
Off-Road Motor Gasoline [3]	53	69	16	NA	NA	NA	NA	NA	16.3
Agriculture [4]	199	225	26	NA	NA	NA	NA	NA	25.5
Total	7018	7665	647	1079.8	214.7	-87.7	-430.2	-161.4	31.7

Terms:
A: Activity Effect, **S**: Structure Effect, **W**: Weather Effect, **EE**: Energy Efficiency Effect, **I**: Interaction Effect

(1) The factorization excludes street lighting. The change in energy use for this component from 1990 to 1998 is shown in the "Other" column.

(2) The factorization was done excluding the non-airline (commercial/institutional and public administration) air sector. The difference in energy use for the non-airline component (-8.8 PJ) is shown in the "Other" column.

(3) The factorization analysis was not done for off-road motor gasoline. The change in energy use for this component from 1990 to 1998 is shown in the "Other" column.

(4) The factorization analysis was not done for the agricultural sector. Chapter 7 shows an aggregate analysis of the sector. The change in energy use for this component from 1990 to 1998 is shown in the "Other" column.

(5) The change in energy use between 1990 and 1998 shown in this column and the sum of the activity, structure, weather, energy efficiency and interaction for passenger and freight transport are slightly different because of the exclusion from the factorization analysis of the non-airline segments in passenger transport. The transport sector differences are reflected at the secondary energy use level; other differences are excluded from the factorization such as agriculture, off-road motor gasoline and street lighting which are included under the "Other" column.

Changes in structure (the mix of activity) also contributed to increased secondary energy use between 1990 and 1998. Most notably, the distribution of sectoral activity shifted toward more energy-intensive activities or components of the Canadian economy during the review period. This shift accounted for 215 petajoules.

Table 2.4 shows that warmer weather helped minimize the increase in secondary energy use between 1990 and 1998. The winter of 1998 was significantly warmer than the 30-year average (based on data provided by Environment Canada), which meant that less energy was used for space heating in 1998 than in 1990, which was also warmer than usual. Had weather been the same in both years, secondary energy use in Canada would have been 88 petajoules higher.

Improved energy efficiency was another factor mitigating the increase in secondary energy use between 1990 and 1998. Had energy efficiency remained at its 1990 level, and only activity levels, structure and weather changed, secondary energy use would have been 430 petajoules higher. Many factors underlie improvements in energy efficiency at the aggregate secondary level. Sectoral trends in energy use and energy efficiency are reviewed in Chapters 3 to 7.

Table 2.5: Factors Influencing Growth in Greenhouse Gas Emissions from Secondary Energy Use, 1990–1998

Sector	Greenhouse Gas Emissions (megatonnes)		Greenhouse Gas Emissions	Energy Use	Greenhouse Gas Intensity of Energy Use
			(percentage change)		
	1990	1998			
Residential	69.8	69.3	-0.8	-2.4	1.7
Commercial	47.6	53.8	13.1	8.9	3.9
Industrial	142.4	155.2	9.0	9.9	-0.8
Transportation	135.1	157.0	16.2	16.2	0.0
Agriculture	13.7	15.9	15.9	12.8	2.7
Total	408.6	451.3	10.4	9.2	1.1

2.3 Trends in the Greenhouse Gas Intensity of Secondary Energy Use

Table 2.5 summarizes the changes in greenhouse gas emissions, secondary energy use and greenhouse gas intensity of energy use between 1990 and 1998 for the economy as a whole and for each end-use sector. As explained earlier, changes in greenhouse gas emissions are the result of changes in both the amount of energy used and in the greenhouse gas intensity of the fuel used.

Greenhouse gas emissions resulting from secondary energy use in Canada increased by 10.4 percent between 1990 and 1998, from 409 megatonnes (CO_2 equivalent) to 451 megatonnes. The main factor affecting the change in emissions was growth in energy use. Across the economy, secondary energy use increased by 9.2 percent, from 7018 petajoules to 7665 petajoules. Had energy use remained at 1990 levels, greenhouse gas emissions would have been 40 megatonnes (CO_2 equivalent) lower in 1998 than actual levels.

The growth in emissions was boosted by a 1.1-percent increase in the greenhouse gas intensity of energy use. Had greenhouse gas intensity not increased, emissions would have been 2.4 megatonnes (CO_2 equivalent) lower in 1998 than actual levels. The increase in greenhouse gas intensity was a result of shifts in the mix of fuels used to meet the growth in energy demand as well as significant changes in the mix of fuels used to generate electricity. Chapters 3 to 7 provide explanations of the fuel shifts that occurred in each end-use sector.

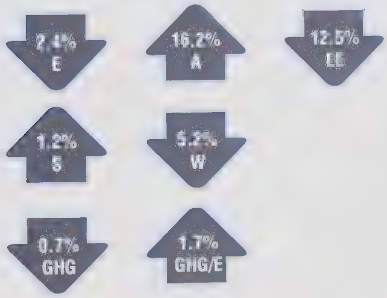
Residential Sector

Definition: The residential sector in Canada includes four major types of dwellings: single-detached homes, single-attached homes, apartments and mobile homes. Energy is used primarily for space heating, space cooling, water heating and operating appliances and lighting.

Highlights

- From 1990 to 1998, energy use (E) in Canada's residential sector decreased by 2.4 percent, or 32 petajoules. This decrease was the result of a combination of factors:
  - There was a significant increase in aggregate activity (A) in the residential sector (measured using an index derived from the number of Canadian households and the floor area of dwellings). Had only activity changed over the period, residential energy use would have increased by 214 petajoules from 1990 to 1998.
  - Structure (S), the percentage of energy used for different end-uses also put some upward pressure on energy consumption. Had only structure changed over the period, residential energy use would have increased by 16 petajoules.
  - Changes in weather (W), specifically an unusually warm winter in 1998, also had a significant impact on energy use. Had only weather changed over the period, residential energy use would have decreased by 68 petajoules.
  - Aggregate energy intensity decreased by 16 percent in the residential sector. However, energy efficiency improved by 12.5 percent. Had only energy efficiency (EE) changed over the period, residential energy use would have decreased by 165 petajoules.
- Greenhouse gas (GHG) emissions from the residential sector were 69.3 megatonnes in 1998, down 0.7 percent from 1990. The discrepancy between the decrease in emissions and the decrease in energy use is primarily due to a switch to more GHG-intensive fuels to produce electricity.

The Energy/Emissions Barometer – Residential Sector



3.1 Overview – Energy Use and Greenhouse Gas Emissions

In 1998, energy use in the residential sector totalled 1288 petajoules, or about 16.8 percent of secondary energy demand in Canada. Greenhouse gas emissions from residential energy use were 69 megatonnes, or about 15.3 percent of total greenhouse gas emissions from secondary energy use.

The residential sector comprises four major types of dwellings: single-detached, single-attached, apartments and mobile homes. As illustrated in Figure 3.1, single-detached dwellings are the predominant type, accounting for about two thirds of the residential floor space in Canada in 1998.

Figure 3.1: Distribution of Floor Space by Type of Dwelling, 1998 (percent)

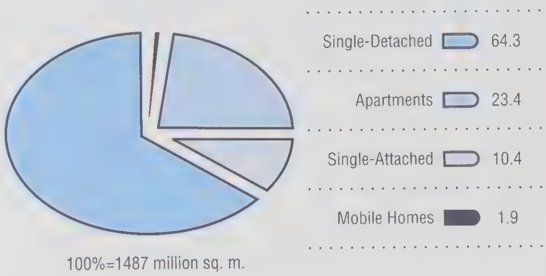
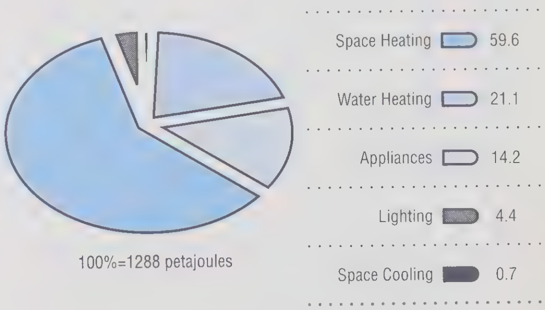


Figure 3.2 shows the five main end-uses of energy in the residential sector. In 1998, 80.7 percent of the energy consumed in this sector was used for space heating and water heating. Appliances and lighting were also major energy users, with space cooling accounting for only a small portion of total energy consumption.

Figure 3.2: Distribution of Residential Energy Use by End-Use, 1998 (percent)

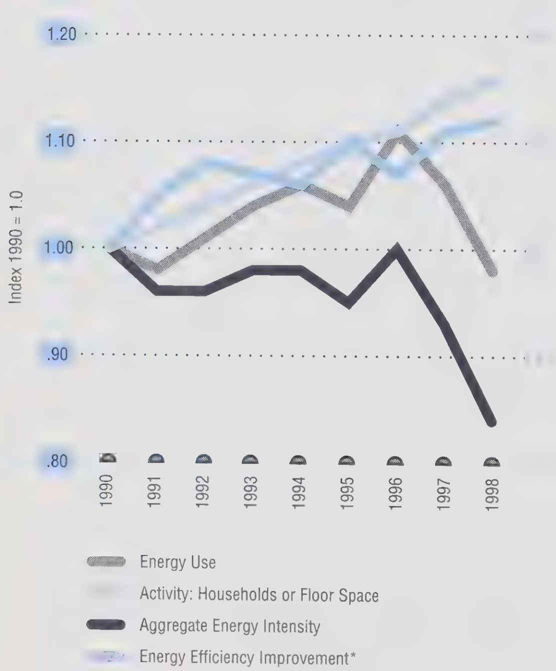


Natural gas and electricity are the two main types of energy used in the residential sector. In 1998, natural gas accounted for 44.6 percent of the total and electricity for 36.2 percent. The energy source varies according to its end use – natural gas is the main source of energy for space and water heating, while most appliances use electricity.

3.2 Trends in Energy Use

Figure 3.3 illustrates the trends in residential sector energy use, aggregate energy intensity, activity and energy efficiency from 1990 to 1998.

Figure 3.3: Residential Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 (index 1990 = 1.0)



*This report presents an index of energy efficiency improvements while previous reports presented an index of the effects of energy efficiency on energy use.

During this period, residential energy use decreased by 2.4 percent, from 1319 petajoules in 1990 to 1288 petajoules in 1998. At the same time, activity increased by 16.2 percent. In the case of the residential sector, activity is measured using an index derived from the number of households and the floor area of dwellings (in the review period, floor area increased by 17.2 percent and the number of households increased by 14.2 percent).[1] Aggregate energy intensity decreased by 16.0 percent and energy efficiency improved by 12.5 percent.

Only two end-uses recorded declines in energy use between 1990 and 1998 – space heating and appliances, which accounted for a 4.0-percent drop in residential energy use. This was offset somewhat by an increase in the use of energy for water heating, space cooling and lighting, which accounted for a 1.6-percent increase in residential energy use. The net result, as noted above, was a 2.4-percent decrease in overall residential energy use.

Growth in the number of households and in floor area are key factors affecting residential energy use. As shown in Figure 3.3, the 16.2-percent growth in activity had a significant impact on residential energy demand. Over the 1990 to 1998 period, close to 1.5 million new households were created in Canada, and the total floor area of dwellings increased by approximately 218 million square metres.

Changes in Fuel and End-Use Shares

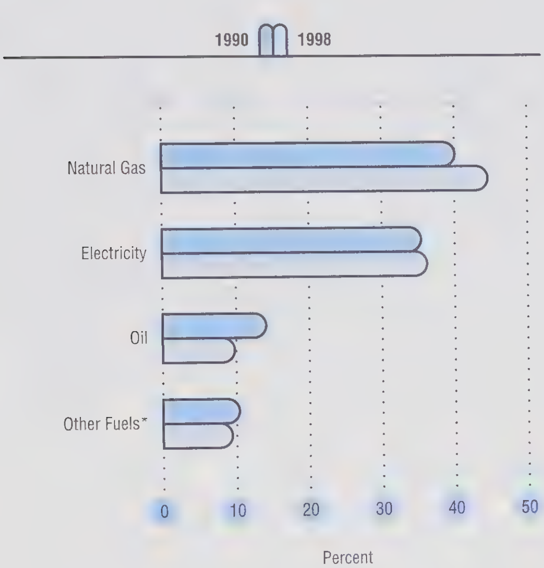
Figure 3.4 provides a breakdown of fuel use in the residential sector in 1990 and 1998. The most notable change in the two years was the move away from oil to natural gas. Oil's share of residential fuel use decreased by 4.4 percentage points between 1990 and 1998, while natural gas's share increased by 4.5 percentage points. Natural gas increased its share of fuel use for space heating by 5.6 percentage points and for water heating by 6.9 percentage points.

Residential energy use decreased by 2.4 percent between 1990 and 1998 despite a 16.2 percent increase in activity.

1 The OEE has changed the way activity is measured in the residential sector. For a discussion of the new approach, see the section "Changes in the Factorization Analysis Methodology: A New Activity Variable," on page 17.

These increases were largely a result of the more widespread availability of natural gas and lower natural gas prices relative to electricity. Oil's share of fuel use for space heating declined by 6.0 percentage points and for water heating by 2.0 percentage points.

Figure 3.4: Residential Energy Fuel Shares, 1990 and 1998 (percent)



* liquefied petroleum gases, coal, steam, wood

Energy end-uses in the residential sector are illustrated, by percentage share, in Figure 3.5. Space heating recorded the largest decline in its share of energy end-use between 1990 and 1998, largely because the winter of 1998 was warmer than the winter of 1990. The shares of all other end-uses increased. Water heating recorded the largest percentage points increase, at 1.6. On the other hand, space cooling recorded the biggest increase in total energy use, at 57.1 percent, as a result of warmer weather in the summer of 1998 and increased sales of air conditioners. Nevertheless, the amount of residential energy used for space cooling – 0.7 percent in 1998, compared to 0.4 percent in 1990 – remains a small amount of the total energy used in the sector.

Figure 3.5: Residential Energy End-Use Shares, 1990 and 1998 (percent)

Changes in the Factorization Analysis Methodology: A New Activity Variable

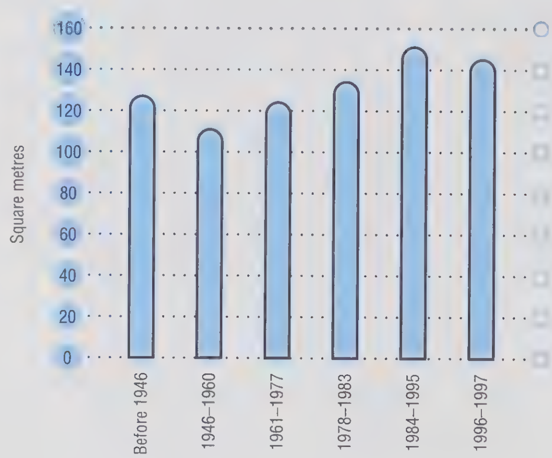
Activity is one of four factors considered by the OEE in its analysis of energy use in the residential sector (the impact of all four factors are discussed later in the chapter). In previous reports, activity was measured as the number of households in Canada. While analysts believed that using the floor area of houses would produce more meaningful results, insufficient data on floor area was available until 1999, when the results of the *1997 Survey of Household Energy Use* (SHEU) became available. This survey was conducted by Statistics Canada on behalf of the OEE. The SHEU data on floor area have now been combined with data on the number of households (also provided by Statistics Canada) to arrive at an estimate of the total floor area of Canadian houses by province, house type and period of construction.

The addition of the floor area variable to the activity measurement is a significant development. While the number of households is a good indicator of activity when assessing energy end-uses such as appliances and water heating (which are affected by the number of occupants in the household), it is less useful for analysing end-uses such as space heating, space cooling and lighting (which do not change notably based on the number of occupants). For these latter end-uses, floor area is a better indicator of activity.

To address this issue and improve its factorization analysis for the residential sector, the OEE has developed an activity index that is a mix of both the number of households and floor space. The factorization results are available for the whole sector as well as for two sub-sectors (household services and floor space services and five end-uses). Floor space services include space heating, space cooling and lighting energy use, while household services include appliances and water heating energy use. The factorization results for the two sub-sectors are weighted according to their share of total residential energy use and then added together to get the sectoral results. Essentially, this means the factorization results for the residential sub-sectors and end-uses are meaningful, but the results for the sector as a whole should be treated with more caution.

This methodology improvement will allow the OEE to account for variations in the floor area of houses over time, which was not previously possible. Suppose, for example, that the number of households was to remain constant over time, but that the floor area of the houses where those households live was allowed to change. Assuming the same number of occupants, it can be surmised that a larger house will require more energy for space heating, space cooling and lighting, but will use the same amount of energy for water heating and appliances. If a trend developed toward larger houses (this has been confirmed by the 1997 SHEU survey, as illustrated in Figure 3.6), the energy intensity of the residential sector (defined as energy over the number of households) would increase, even though the larger houses might require less energy per square metre than smaller houses.

Figure 3.6: Average Floor Area of Dwellings by Vintage (square metre)



Source: 1997 Survey of Household Energy Use

However, now that data on floor area are available, changes in energy intensity will no longer be dependent on the size of the house. For this reason, the results of the factorization analysis presented in the current report will differ somewhat from the results described in previous reports. Having pointed out this discrepancy, the results presented here and in previous reports are reasonably consistent, since the evolution of the two activity variables was similar between 1990 and 1998 (see Figure 3.7).

Figure 3.7: Households and Floor Area Evolution, 1990–1998 (index 1990 = 1.0)

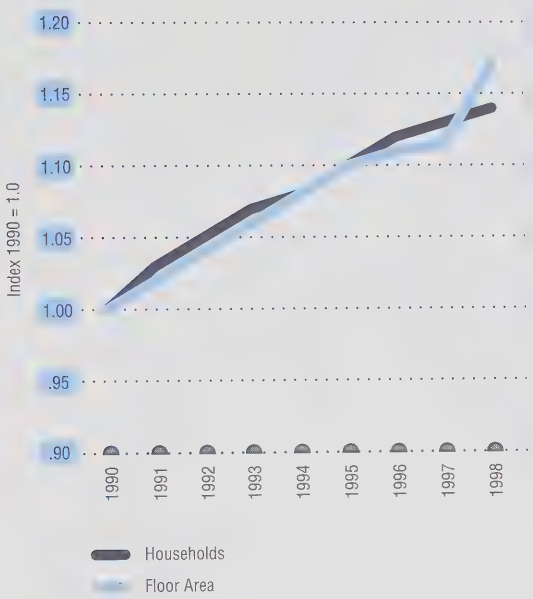


Figure 3.8: Factors Influencing Growth in Residential Energy Use, 1990–1998 (petajoules)

* Represents the effect of energy efficiency improvements on energy consumption.

** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

3.2.1 Factors Contributing to Changes in Energy Use

In this report, changes in residential energy use are attributed to four broad factors: changes in activity, changes in weather, changes in structure and changes in energy efficiency. The results of the OEE's factorization analysis (shown in Figure 3.8) reveal that growth in residential energy use between 1990 and 1998 was driven in large part by growth in activity. This increase was offset by significant improvements in energy efficiency, as well as changes in weather. Structural changes had a minor impact on energy use in the residential sector.

Specifically, the analysis revealed that:

- had only activity changed over the period, residential energy use would have increased by 214 petajoules between 1990 and 1998;
- had only weather changed over the period, residential energy use would have decreased by 68 petajoules between 1990 and 1998;[2]
- had only structure (the percentage shares of energy end-uses) changed over the period, residential energy use would have increased by 16 petajoules between 1990 and 1998; and
- had only energy efficiency changed over the period, residential energy use would have decreased by 165 petajoules between 1990 and 1998.[3]

2 The 1998 heating season was significantly warmer than in 1990 (340 fewer degree-days, a decrease of 8.3 percent), which reduced the demand for space heating energy. However, more energy was required for space cooling because the summer of 1998 was warmer than the summer of 1990.

3 Of this amount, 103 petajoules can be attributed to improved space heating energy efficiency, 37 petajoules to improved appliance energy efficiency, 20 petajoules to improved water heating energy efficiency and 5 petajoules to improved lighting energy efficiency. The energy efficiency of space cooling had no impact over the period.

3.2.2 Factors Influencing Space Heating Energy Use

As illustrated in Figure 3.9, the amount of energy required for residential space heating declined by 50 petajoules between 1990 and 1998. This decline is a result of a combination of factors:

- increased activity (growth in the amount of heated floor area) resulted in higher demand for space heating. Had only activity changed, energy use for space heating would have increased by 140 petajoules between 1990 and 1998.
- an unusually warm winter in 1998 helped to offset the increase in activity. Had only weather changed, energy use for space heating would have decreased by 68 petajoules between 1990 and 1998. Even though the 1998 winter was significantly warmer than usual, warmer than usual winter temperatures were also observed in 1990. In fact, the 1990 winter was 7.5 percent warmer than usual while the 1998 winter was 15.2 percent warmer. This means that the 1998 winter is only 8.3 percent warmer than the 1990 winter, which explains why the impact of weather on energy use is lower than might be expected.
- energy efficiency improvements in space heating equipment and the thermal characteristics of houses also helped offset the increase in activity. Had only energy efficiency changed, energy use for space heating would have decreased by 103 petajoules between 1990 and 1998.

The decline in space heating energy intensity over the review period was a result of several factors, primarily improvements in the efficiency of space heating equipment, improvements in the thermal characteristics of new and existing houses, and increases in heated living area. These developments are discussed in further detail in the following pages.

Figure 3.9: Factors Influencing Growth in Residential Space Heating Energy Use, 1990–1998 (petajoules)

* Represents the effect of energy efficiency improvements on energy consumption.

** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

The warm 1998 winter helped offset the effect of increased activity on residential energy use.

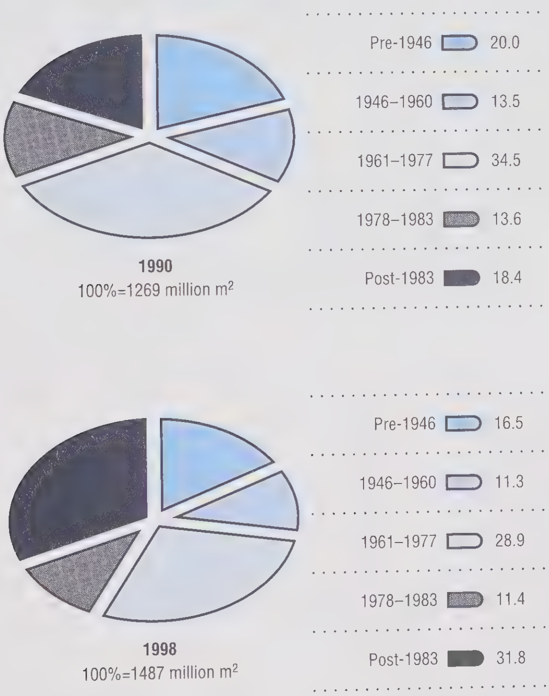
The Market Penetration of New Homes

New dwellings added to the housing stock since 1984 tend to be better insulated and have more efficient equipment than existing homes. This is a result of two factors:

- the development of new and more energy-efficient technologies; and
- revised building codes that have generally increased minimum energy standards for new construction.

However, changes in the proportion of old versus new homes in the Canadian housing stock tend to occur slowly over time. Figure 3.10 shows that the proportion of older homes (those built before 1960) in the housing stock declined from 33.5 percent in 1990 to 27.9 percent in 1998. Over the same period, the proportion of newer homes (those built between 1984 and 1998) in the stock increased from 18.4 percent to 31.8 percent. This relatively slow pace of change reflects the longevity of housing in Canada: older homes are slow to be retired, which means that it takes time for new housing to capture a larger share of the overall housing stock.

Figure 3.10: Housing Stock Floor Area by Vintage, 1990 and 1998 (percent)



Improved Building Shells

New Houses

As noted earlier, the new houses being built today tend to be more energy efficient than older houses. This is illustrated in Table 3.1, which shows, for example, significant differences in air leakage between older (pre-1983) and newer (post-1983) houses. While the results of the *1997 Survey of Household Energy Use* show that an average of 32 percent of all Canadian households experience air leaks from their windows, the problem declines to an average of 22 percent for homes built in 1990 or later.

Table 3.1 also reveals widespread use of double-glazed windows in newer homes. Over the past few years, the use of windows that have two layers of glazing covered with a low-emissivity coating (which reflects heat energy back to its source) and filled with an inert gas (argon) has improved the thermal resistance of windows by 50 percent. In 1998, these windows accounted for about 32 percent of total window sales. They generally perform better than triple-glazed windows and are less expensive to purchase, which could explain why triple-glazed windows are not used in more houses (see Table 3.1).

Existing Stock of Houses

Although older houses are not as energy efficient as new construction, energy efficiency improvements are often made as homes are renovated over time. According to the *1997 Survey of Household Energy Use*, 4 percent of homeowners improved insulation levels in their attics, walls or basements in 1997, while 10 percent added or replaced windows. Of the latter group, 60 percent reported that they had installed standard double-glazed windows.

More Energy-Efficient Space Heating Equipment

Significant improvements have been achieved in the energy efficiency of space heating equipment. In 1998, the annual fuel utilization efficiency (AFUE) rating of new residential oil furnaces was 72 percent, compared to 63 percent in 1990. For natural gas furnaces, the AFUE rating improved from 71 percent in 1990 to 87 percent in 1998.

Figure 3.11 shows a trend toward increased use of energy-efficient units in the Canadian market. The proportion of medium- and high-efficiency gas furnaces installed in Canadian houses climbed from 7.6 percent in 1990 to 22.3 percent in 1998. Conventional natural gas furnaces are no longer sold in Canada. In 1988, mid-efficiency furnaces accounted for 70 percent of total sales and high-efficiency units for the remaining 30 percent of sales.

Figure 3.11: Natural Gas Furnace Stocks by Efficiency Level, 1990 and 1998 (percent)

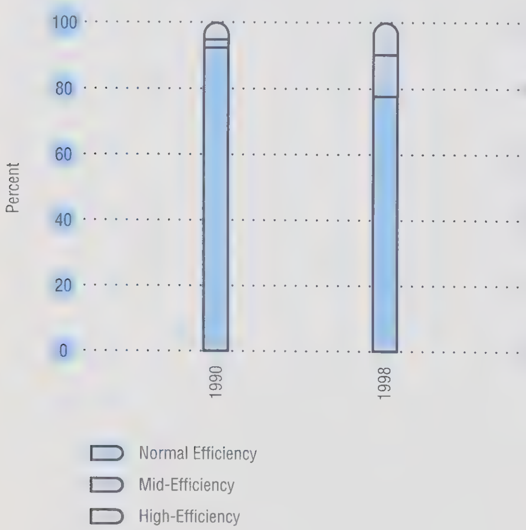


Table 3.1: Thermal Characteristics of Housing Envelope in Canada, 1997 (percentage of households)

	Before 1941	1941–1960	1961–1977	1978–1982	1983–1989	1990–1997	All Houses
Windows							
Triple-Pane	7	9	8	7	7	6	7
Double-Pane	63	74	85	91	90	92	82
Air Leaks Around the Windows	43	31	32	39	27	22	32
Air Exchanger (have and use)							
With Heat Recovery	0	1	3	2	8	11	4
Without Heat Recovery	2	3	5	7	12	15	7
Heated Basement	66	79	85	83	83	86	81

Source: *1997 Survey of Household Energy Use*

Figure 3.12: Factors Influencing Growth in Residential Appliance Energy Use, 1990–1998 (petajoules)

* Represents the effect of energy efficiency improvements on energy consumption.

** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

Bigger Houses

As noted earlier in this chapter, the *1997 Survey of Household Energy Use* collected data on the average floor area of Canadian houses. This information, combined with data on the number of Canadian households, has resulted in the first reliable estimate of the total floor space of Canada's housing stock. A clear trend has emerged since the 1960s toward constructing larger new houses (see Figure 3.6 on page 18).

Fuel Switching

The issue of fuel switching is mentioned briefly on page 16, under the section "Changes in Fuel and End-Use Shares." Specifically in relation to space heating, natural gas increased its share of the residential market from 47.7 percent in 1990 to 53.3 percent in 1998. To a lesser extent, there was also fuel switching for space heating from oil to electricity. Natural gas and electric furnaces both tend to be more efficient than oil furnaces, which contributed to an overall decline in space heating energy intensity.

3.2.3 Factors Influencing Appliance Energy Use

As illustrated in Figure 3.12, energy use by appliances decreased by 2 petajoules between 1990 and 1998. This decrease is a result of:

- growth in activity (the number of Canadian households), which increased appliance energy use by 26 petajoules between 1990 and 1998;
- changes in structure (increased market penetration of various appliances), which increased appliance energy use by 11 petajoules; and
- appliance efficiency improvements, which helped offset the increase in activity and changes in structure. Had only energy efficiency changed, appliance energy use would have declined by 34 petajoules between 1990 and 1998.

The structural changes noted above are illustrated in Figure 3.13, which shows the market penetration rates of 10 types of appliances between 1990 and 1998. Among major appliances, the most significant increases were recorded by dishwashers, whose market penetration went from 42 percent of households in 1990 to 51 percent of households in 1998. Electric clothes dryers also recorded a significant increase in market penetration, from 70 percent of households in 1990 to 76 percent in 1998. The percentage of Canadian households that had refrigerators and clothes washers also increased between 1990 and 1998, although to a lesser extent. About 22 percent of households had two or more refrigerators in 1998, compared to about 18 percent in 1990.

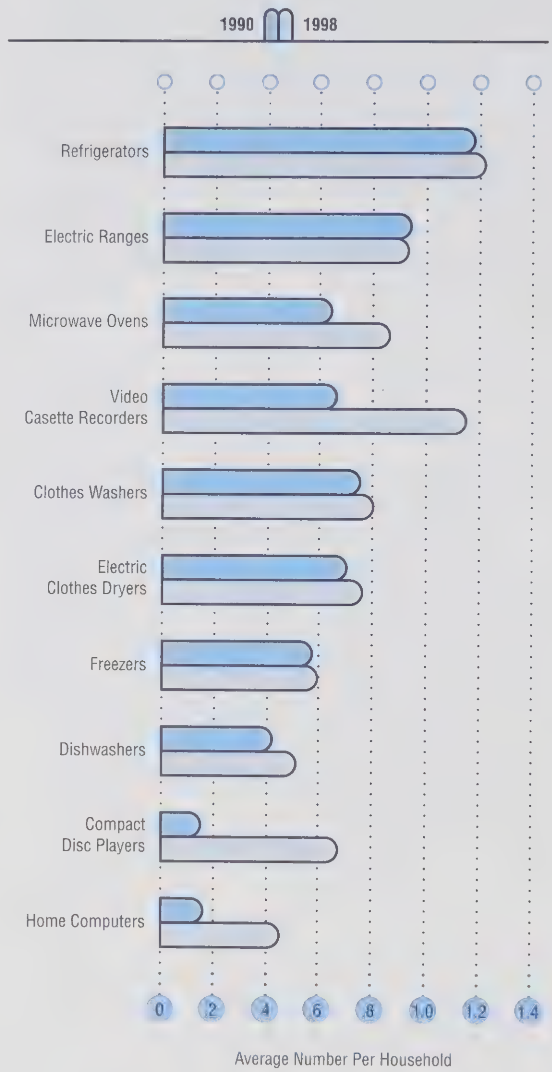
The increased availability and more aggressive marketing of "new" electric devices has also increased appliance energy consumption in the residential sector. Such new products include compact disc players, home computers, video cassette recorders and DVD players. Among the more established products, compact disc players and computers achieved the greatest increase in market penetration between 1990 and 1998. In 1990, for example, only 15 percent of households had a compact disc player, compared to 67 percent in 1998. The proportion of households owning a computer increased from 16 percent in 1990 to 45 percent in 1998.

DVD players came onto the market only in early 1997, but approximately 110 000 units had been sold in Canada by the end of 1998.[4]

Microwave ovens have also recorded rapid growth in market penetration. The percentage of Canadian households with microwave ovens increased from 64 percent in 1990 to 86 percent in 1998. According to the *1997 Survey of Household Energy Use*, 70.0 percent of households which own a microwave oven use it daily to reheat food, while 11.7 percent use it daily to cook food.

Many other electric appliances found in Canadian homes (e.g., televisions, radios, clocks, small kitchen appliances, etc.) also have the potential to consume large quantities of energy. According to a 1996 study conducted by the Canadian Residential Energy End-Use Data and Analysis Centre (CREEDAC), in 1993 such appliances consumed 1300 kWh per year per household,[5] which is equivalent to the energy consumed by two new refrigerators.

Figure 3.13: Penetration Rates for Household Appliances, 1990 and 1998 (average number per household)



4 This number was obtained from U.S. sales data collected by the Consumer Electronics Association. The data is available at http://www.thedigitalbits.com/articles/cemadvdsales.html. A factor of 10% was applied to the U.S. data to obtain a Canadian figure.

5 Canadian Residential Energy Use Data and Analysis Center, *Residential Electrical Energy Use Associated with Miscellaneous Appliances in Canada*. Halifax, 1996.

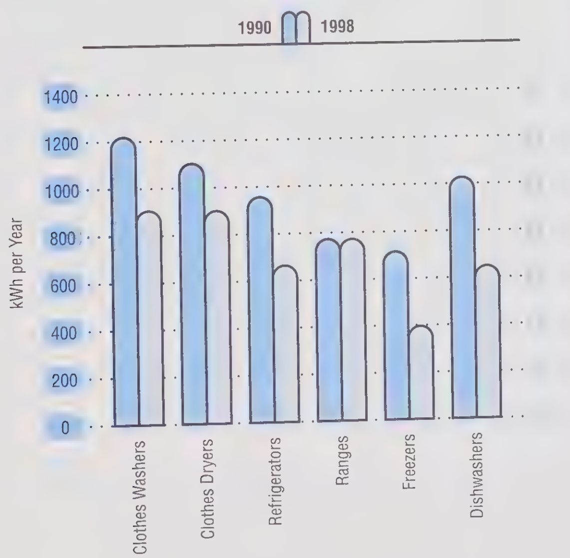
More Energy-Efficient Appliances

The 2-petajoule decrease in appliance energy use noted earlier (see page 23) would have been far greater if not for substantial activity growth between 1990 and 1998. This growth contributed to a rise in appliance energy use of about 26 petajoules. However, the substantial improvements in appliance energy efficiency that were observed more than compensated for this growth in activity.

As illustrated in Figure 3.14, most new appliances were significantly more energy efficient in 1998 than in 1990. For example:

- new freezers were 44.6 percent more efficient in 1998 than in 1990;
- new dishwashers were 36.8 percent more efficient; and
- new refrigerators were 30.6 percent more efficient.

Figure 3.14: Energy Efficiency Trends of Appliances, 1990 and 1998 (kWh per Year)



Efficiency Gains Outweigh Move to Bigger Appliances

Manufacturers of major household appliances have dramatically improved the energy efficiency of their products. While some of these gains have been offset by consumer trends toward buying larger appliances than in the past, the energy efficiency improvements still outweigh the larger size of new appliances. For example, an average refrigerator sold in 1998 consumes 36.6 percent less energy than the average refrigerator found in the overall stock. The increase in energy efficiency in new appliances has had an impact on the average energy efficiency of the total stock of refrigerators. In 1998, an average refrigerator found in a Canadian home (all types included) consumed about 1048 kWh per year, compared to 1525 kWh in 1990. This 31.3 percent reduction in energy use was possible even though the average size of refrigerators increased by 9.5 percent between 1990 and 1998.

Please refer to *Table A* for *Appliance Efficiency Gains for Refrigerators.*

Table A: Appliance Annual Energy Consumption (kWh/Year)

	1990 Stock	1998 Stock	1998 New Unit
Refrigerator	1525	1048	664
Freezer	1291	896	396
Dishwasher	1275	924	648
Clothes Washer	1326	1118	905
Electric Clothes Dryer	1314	1087	901

Sources: Residential Energy Use Model (1999) and CAMA (1998)

Overview of the Appliance Market

Figure A provides data on the four major energy-consuming household appliances. A visual analysis of the data indicates that models sold in 1990 consumed more energy per unit than models sold in 1998. In some cases, the unit energy consumption of clothes washers, dishwashers and refrigerators decreased even when the size of the appliance increased.

The only exception is for freezers, where the data seem to indicate that 1998 models were less efficient than those sold in 1990. These data are distorted by the fact that some freezers on the market in 1998 were significantly larger than those available in 1990. However, as shown in Figure B2, 83.1 percent of the freezers sold in 1998 had lower energy requirements than almost all of the freezers sold in 1990. As a result, large freezers with high energy requirements had only a minor impact on the overall energy consumption of the stock of freezers sold in 1998.

Please refer to Figures A1 through A4 and B1 through B2 for Appliance Energy Consumption.

Figure A1: Unit Energy Consumption for Clothes Washers

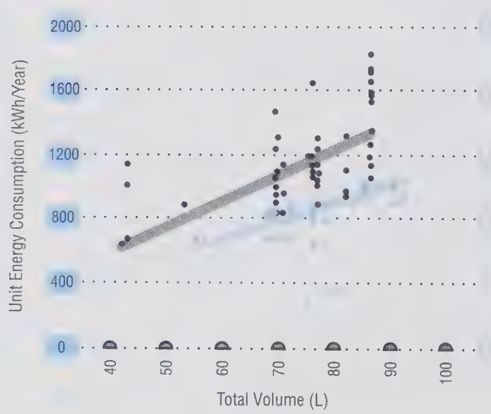


Figure A2: Unit Energy Consumption for Dishwashers

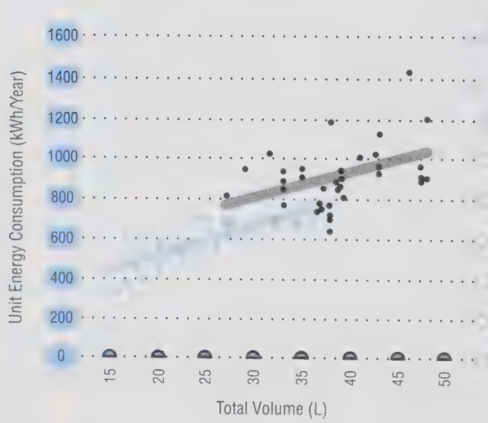


Figure A3: Unit Energy Consumption for Freezers

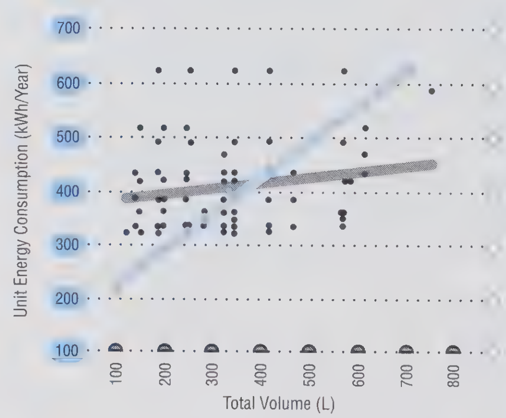


Figure A4: Unit Energy Consumption for Top-Mount Auto-Defrost Refrigerators

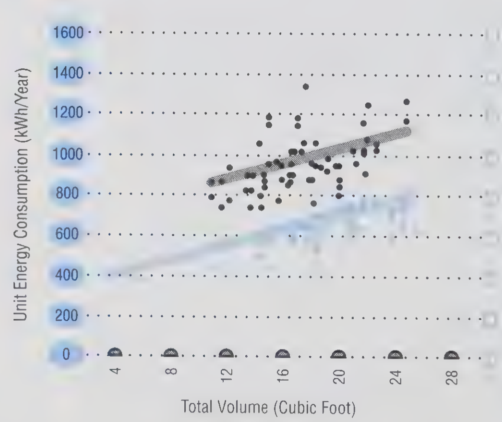


Figure B1: Shipments – Type 3 Refrigerators

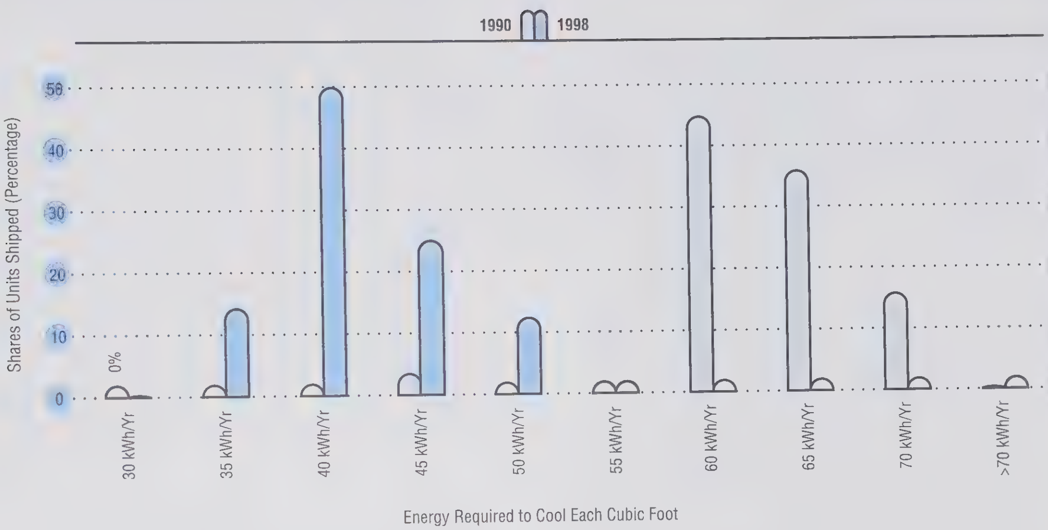
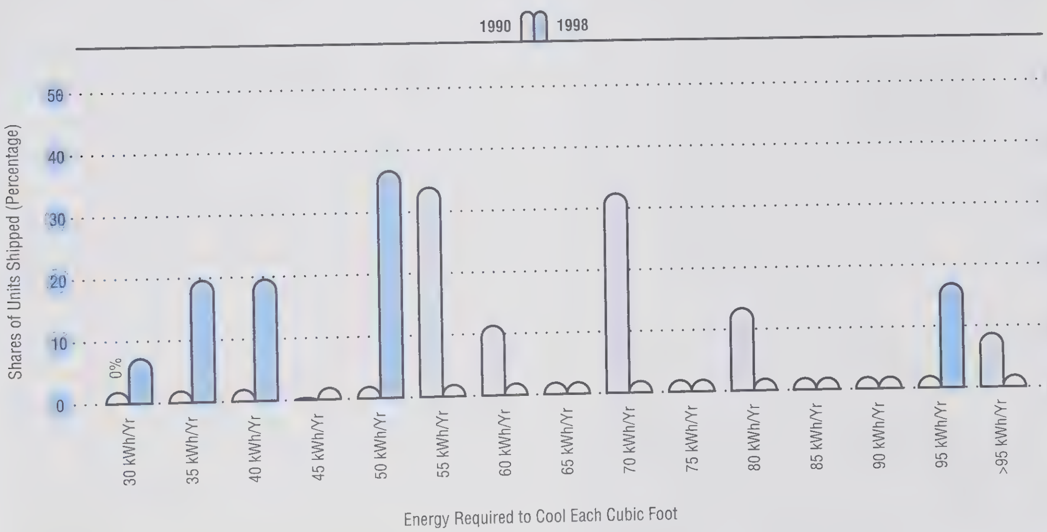


Figure B2: Shipments – Type 10 Freezers



3.2.4 Factors Influencing Other Energy End-Uses

Water Heating Energy Use

The amount of energy used for residential water heating increased by 14 petajoules between 1990 and 1998. Growth in the number of households (as well as the fact that more households now have two water-using appliances: a dishwasher and a clothes washer[6]) resulted in a 37-petajoule increase in energy use for water heating. This increase was partially offset by significant improvements in the energy efficiency of water heating equipment. New dishwashers were 36.8 percent more energy efficient in 1998 than in 1990, and new clothes washers were 25.7 percent more energy efficient. Had only energy efficiency changed over the period, energy use for residential water heating would have decreased by 26 petajoules between 1990 and 1998.

Another factor offsetting the increase in energy use for water heating was a small decrease in household size – in other words, the number of persons per household. The size of households decreased by 3.8 percent between 1990 and 1998 (from 2.62 persons per household in 1990 to 2.52 in 1998).[7]

Space Cooling Energy Use

Space cooling accounted for less than 1 percent of total residential energy use in 1998. However, the use of air conditioners is growing. In 1998, 21.2 percent of residential floor area in Canada was serviced by a central air conditioner, compared to 14.5 percent in 1990. The 1997 Survey of Household Energy Use revealed that approximately 47 percent of households equipped with a central air conditioner use it to cool their homes for at least half of the summer.

As is the case with household appliances and heating equipment, manufacturers have improved the energy efficiency of air conditioning units over the past decade.

Lighting Energy Use

Electricity for lighting accounted for 4.4 percent of total residential energy use in 1998, based on a study conducted by the Canadian Residential Energy End-Use Data and Analysis Centre. Using data collected through the *1993 Survey of Household Energy Use*, CREEDAC has estimated that the average annual energy consumption of lighting is about 1767 kWh per dwelling.

3.3 Trends in Greenhouse Gas Emissions

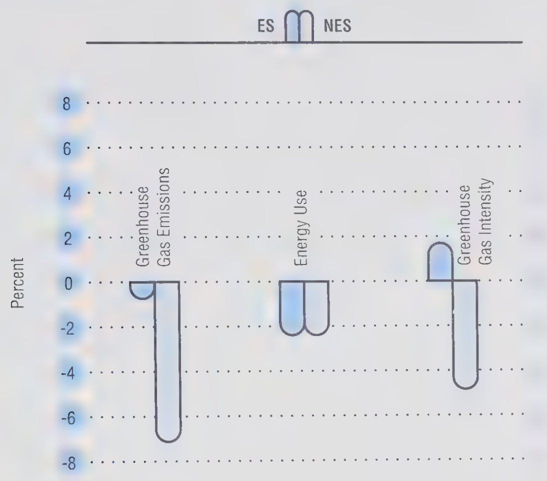
Energy use in the residential sector produced 69.3 megatonnes of greenhouse gas emissions in 1998, a decrease of 0.7 percent from the 1990 level (69.8 megatonnes). Almost 41.6 percent of 1998 residential emissions were indirect emissions, meaning that they resulted from electricity generation (this issue is discussed further below). Figure 3.15 shows that the greenhouse gas intensity of residential energy use increased by 1.7 percent over the review period when emissions from electricity generation are included. If we exclude those emissions, the greenhouse gas intensity of residential energy use decreases by 4.9 percent instead of increasing.

Greenhouse gas emissions in the residential sector were 69 megatonnes in 1998, a decrease of 0.7 percent from 1990

6 Approximately 88 percent of the energy used by dishwashers and 92 percent of the energy used by clothes washers is used to heat the water. The remaining energy is used by the appliance's electrical motor.

7 Statistics Canada, *Household Facilities and Equipment* (cat. no. 64-202), Ottawa, Ontario, October 1995; and Statistics Canada, *Survey of Household Spending* (Cat. No. 62F0041), Ottawa, Ontario, December 1999.

Figure 3.15: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Residential Sector, 1990–1998 (percent)

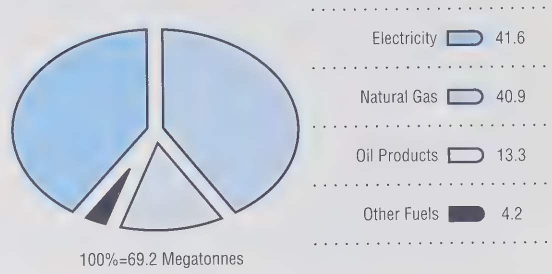


ES: Electricity End-Use Emissions Scenario
NES: No Electricity End-Use Emissions Scenario

There is a significant discrepancy in the rate of decline in greenhouse gas emissions (0.7 percent) and the rate of decline in residential energy use (2.4 percent) between 1990 and 1998. This is due to changes in the types of fuels used to generate electricity. Those changes are explained in more detail in Chapter 2 of this report.

As a result of these changes, electricity has displaced natural gas as the largest source of greenhouse gas emissions from the residential sector. As shown in Figure 3.16, electricity accounted for 41.6 percent of the sector's emissions in 1998, compared to 40.9 percent for natural gas.

Figure 3.16: Residential Greenhouse Gas Emissions by Fuel Type, 1998 (percent)



From an energy end-use perspective, space and water heating accounted for 77.9 percent of residential sector greenhouse gas emissions in 1998 (see Figure 3.17). Two developments are of note:

- The share of emissions related to space heating decreased by 4.1 percentage points between 1990 and 1998. This is consistent with the fact that space heating made the largest contribution to the overall decrease in residential sector energy use during the review period.
- The share of emissions related to water heating increased by 1.5 percentage points between 1990 and 1998. This is a result of two factors: the 5.3-percent increase in water heating energy demand over the period, and the higher greenhouse gas intensity of electricity in the latter part of the review period.

Appliances, lighting and space cooling all recorded increases in their share of greenhouse gas emissions over the review period, as a result of both increased activity and the increased greenhouse gas intensity of electricity (which accounts for 98.3 percent of the energy consumed by these three end-uses). Specifically:

- emissions from appliance energy use increased by 8.5 percent, even though appliance energy use decreased 1.2 percent;
- emissions from lighting energy use increased by 16.9 percent; and
- emissions from space cooling energy use increased by 73.0 percent.

Figure 3.17: Residential Greenhouse Gas Emissions by End-Use, 1990 and 1998 (percent)

Trends in Greenhouse Gas Intensity – 1990–1998

If we go back to Figure 3.15, we can see that the greenhouse gas intensity of residential energy use increased by 1.7 percent over the review period when emissions from electricity generation are included, going from 52.9 tonnes per terajoule in 1990 to 53.8 tonnes per terajoule in 1998. Had it not been for this increase in intensity, greenhouse gas emissions from the sector would have decreased by 2.4 percent, rather than 0.7 percent over the review period. This would have resulted in greenhouse gas emissions for the residential sector of 68 megatonnes in 1998 instead of the 69 megatonnes that was observed.

In the case where electricity-related emissions are excluded from the total, the greenhouse gas intensity of residential energy use decreases by 4.9 percent, going from 33 tonnes per terajoule in 1990 to 31 tonnes per terajoule in 1998. Had this decline in intensity not occured, greenhouse gas emissions (excluding electricity) for the residential sector would have been 42.5 megatonnes in 1998 instead of the 40.5 megatonnes that was observed.

Two factors have contributed to the increase in greenhouse gas intensity. First, there was a shift in end-use fuel shares toward less intensive fuels (see Figure 3.4 on page 17). Oil's share of residential energy use decreased by 4.4 percentage points between 1990 and 1998, while natural gas's share increased by 4.5 percentage points. Since natural gas is less GHG intensive than oil, this shift had the effect of lowering the GHG intensity of energy use in the residential sector. However, changes in the fuel mix used to generate electricity – which are discussed in Chapter 2 – more than offset this downward pressure.

Changes in the fuel mix used to generate electricity more than offset the shift toward less GHG-intensive fuels.

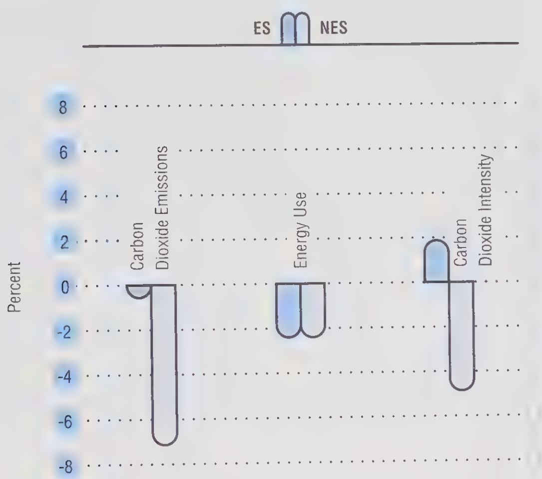
3.4 Trends in Carbon Dioxide Emissions

Energy use in the residential sector resulted in carbon dioxide emissions of 66.9 megatonnes in 1998, which makes up 96.7 percent of all greenhouse gas emissions for this sector. Most of the remaining greenhouse gas emissions come from methane (which represent 2.5 percent of the total greenhouse gas residential emissions). Wood use was responsible for 98.1 percent of residential methane emissions in 1998.[8] This represents a decrease of 0.6 percent from the 1990 level (67.3 megatonnes). Almost 43 percent of 1998 residential carbon dioxide emissions were indirect emissions, meaning

8 The wood-related greenhouse gas emissions that are presented in this report are lower than those presented in Environment Canada's *Canada's Greenhouse Gas Inventory 1997*. The difference arises because NRCan and Environment Canada do not use the same estimate of wood consumption, NRCan's being lower.

that they resulted from electricity generation. Figure 3.18 shows that the carbon dioxide intensity of residential energy use increased by 1.9 percent over the review period, when electricity-related emissions are included. There is a 4.9-percent drop in carbon dioxide intensity if electricity-related emissions are excluded from the analysis.

Figure 3.18: Growth in Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, Residential Sector, 1990–1998 (percent)

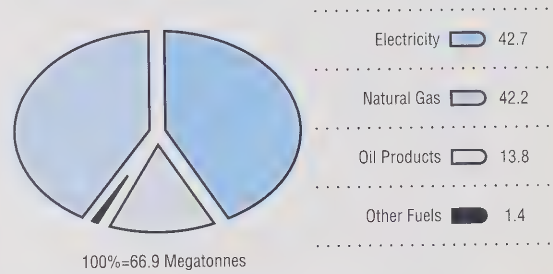


ES: Electricity End-Use Emissions Scenario
NES: No Electricity End-Use Emissions Scenario

As can be seen from Figure 3.18, residential energy use decreased faster than carbon dioxide emissions between 1990 and 1998 (energy use decreased by 2.4 percent while carbon dioxide emissions decreased by 0.6 percent). This is what explains the 1.9-percent increase in carbon dioxide intensity that is mentioned above. As was the case for greenhouse gas emissions, this increase in carbon dioxide intensity is mainly due to changes in the fuel mix used to generate electricity.

As a result of changes in the mix of fuels used to generate electricity, electricity has displaced natural gas as the largest source of carbon dioxide emissions from the residential sector. As shown in Figure 3.19, electricity accounted for 42.7 percent of the sector's emissions in 1998, compared to 42.2 percent for natural gas. The third biggest source of carbon dioxide emissions in the residential sector is oil, which accounted for 13.8 percent of carbon dioxide emissions in 1998.

Figure 3.19: Residential Carbon Dioxide Emissions by Fuel Type, 1998 (percent)



Trends in Carbon Dioxide Intensity – 1990–1998

The average carbon dioxide intensity of energy use in the residential sector increased by 1.9 percent over the review period, from 51 tonnes per terajoule in 1990 to 52 tonnes per terajoule in 1998. Had it not been for this increase, carbon dioxide emissions from the sector would have decreased by 2.4 percent, rather than 0.6 percent. The same factors which came into play in the case of greenhouse gas emissions can explain this increase in carbon dioxide intensity (see section 3.3).

3.5 The Data Situation

Aggregate data on residential energy use are reported on a quarterly basis in Statistics Canada's QRESD (Cat. No. 57-003). Additional data on the characteristics of residential equipment and housing are collected in Statistics Canada's *Survey of Household Spending*, which replaced the previous *Household Facilities and Equipment Survey*.

Additional information has also been collected through two types of surveys sponsored by the National Energy Use Database (NEUD) Initiative: stock surveys and flow surveys.

Stock surveys have two main goals. First, they aim to collect information on the characteristics of energy-using appliances and equipment, the state of dwellings and the building stock, and the profile of consumers (including consumption habits). Their second goal is to collect data on the annual energy consumption of households. Two stock surveys have now been conducted – the *1993 Survey of Household Energy Use* and the *1997 Survey of Household Energy Use*.[9] NEUD is now planning for the next survey.

Flow surveys gather information on variables affecting the housing stock, such as the characteristics of new equipment, new housing and retrofit activities. NEUD has sponsored four flow surveys: the *Survey of Canadian New Household Equipment Purchases* 1994 & 1995, the *Survey of Houses Built in Canada* in 1994, and the *Home Energy Retrofit Survey* (which was conducted in both 1994 and 1995). NEUD has also obtained data on new appliance sales between 1990 and 1998 from the Canadian Appliance Manufacturers Association.

Since the previous report, the principal change made to the modelling methodology and database for the residential sector was the inclusion of the floor area of houses, by province, house type and vintage. These data are now used to derive the space heating load of houses and are also used in the factorization analysis.

9 Although this latter survey collected data for the 1997 calendar year, the survey was actually conducted in 1998.

Commercial Sector

Definition: The commercial sector in Canada includes activities related to trade, finance, real estate services, public administration, education and commercial services (including tourism).

Street lighting is not included in the numbers reflecting the factorization analysis as it does not relate to floor space activity.

Highlights

- From 1990 to 1998, energy use (E) in Canada's commercial sector increased by 9.1 percent, or 78 petajoules (excluding street lighting). Including street lighting, energy use increased by 8.9 percent, or 77 petajoules. This growth was the result of:
  - a 13.8 percent increase in activity (A) (measured by floor space). Had only activity changed over the period, energy use would have increased by 118 petajoules.
  - changes in weather (W) conditions, including warmer summers and winters in 1998 than in 1990. Had only weather changed over the period, energy use would have decreased by 20 petajoules.
  - minor changes in structure (S) (the distribution of floor space between different types of buildings). Had only structure changed over the period, energy use would have increased by 3 petajoules.
  - aggregate energy intensity decreased by 4.1 percent form 1990 to 1998 while energy efficiency (EE) improved by 2.4 percent. Had only energy efficiency changed over the period, energy use would have decreased by 18 petajoules.
- Greenhouse gas emissions (GHG) from the commercial sector increased by 13.1 percent from 1990 to 1998. A big portion of this increase was due to the growth in energy use. The remainder is mainly attributed to an increase in the use of fossil fuels for electricity generation resulting in a 3.9 percent increase in the greenhouse gas (GHG/E) intensity of energy use.

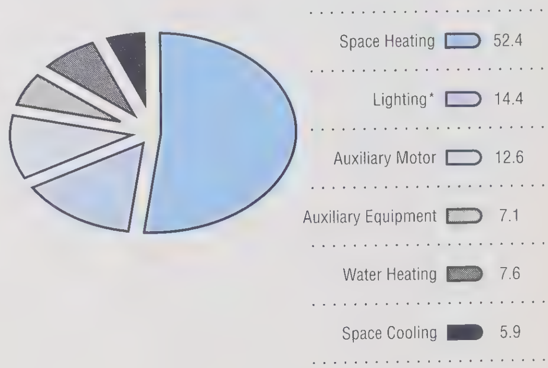
The Energy/Emissions Barometer – Commercial Sector[1]

4.1 Overview – Energy Use and Greenhouse Gas Emissions

In 1998, energy use by the commercial sector totalled 944 petajoules (including street lighting), or about 12.3 percent of secondary energy demand in Canada. Excluding street lighting, energy use totalled 936 petajoules. Total greenhouse gas (GHG) emissions in the commercial sector were 54 megatonnes of CO_2 equivalent, or about 11.9 percent of total GHG emissions from secondary energy use. In the commercial sector, carbon dioxide emissions from energy use represented 99.5 percent of total GHG, methane (CH_4) and nitrous oxide (N_2O) emissions being relatively small in this sector.

As indicated in Figure 4.1, space heating was by far the largest end-use of energy in the commercial sector in 1998, accounting for 52.4 percent of total energy use. This was followed by lighting (excluding street lighting) at 14.4 percent and motive power (e.g., pumping and ventilation in buildings) at 12.6 percent. Water heating, space cooling and electric plug load accounted for the remaining 20.6 percent of energy end-use.

Figure 4.1: Distribution of Commercial Energy Use by End-Use, 1998 (percent)



*Excludes Street Lighting

1 For the commercial sector, street lighting is included in the changes in energy use (E), greenhouse gas (GHG) emissions and greenhouse gas intensity (GHG/E). However, they are excluded from the factorization analysis, i.e., activity (A), energy efficiency (EE), structure (S) and weather (W), because there is no floor space activity associated with street lighting.

In 1998, electricity provided 45.7 percent of the energy used in the commercial sector, followed closely by natural gas at 44.2 percent (see Figure 4.2). Oil products accounted for 6.8 percent of commercial energy use, with the balance split between liquefied petroleum gases, coal and steam.

Figure 4.2: Distribution of Commercial Energy Use by Fuel Type, 1998 (percent)

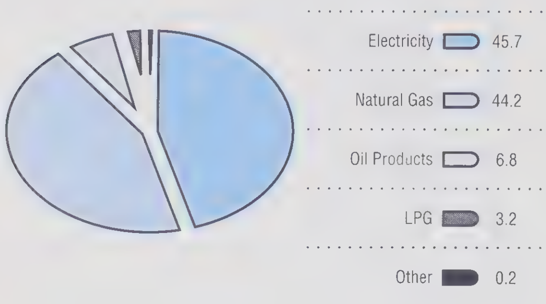
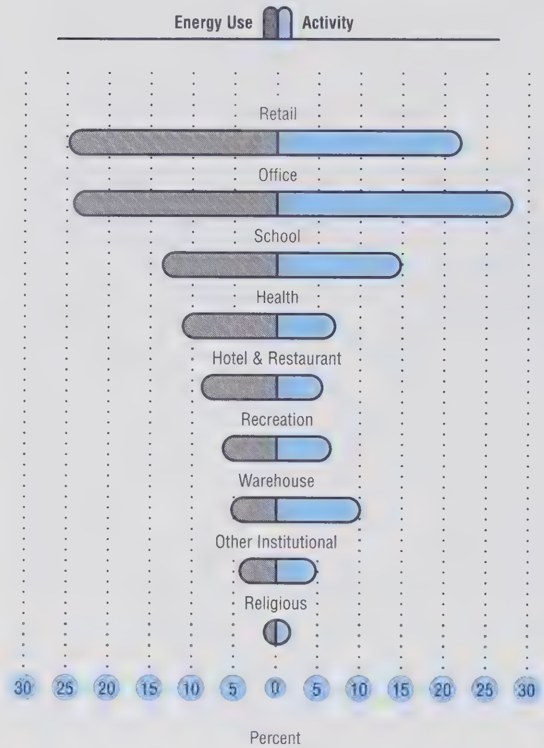


Figure 4.3 provides a breakdown of commercial energy use and activity by building type in 1998 (for the commercial sector, activity is measured by the amount of floor space occupied). Retail, office, educational and health care buildings accounted for a combined total of 73.9 percent of commercial energy use. For the most part, the share of activity for each building type was approximately the same as the share of energy use, with three exceptions:

- in health care facilities, the share of energy use was higher than the share of floor space because of the energy-intensive nature of health care activities;
- hotels/restaurants also had a higher share of energy use than of activity; and
- warehouses had a higher share of activity than of energy use, an indication that the demand for energy-related services in these buildings is minimal.

Figure 4.3: Distribution of Commercial Energy Use and Activity by Building Type, 1998 (percent)



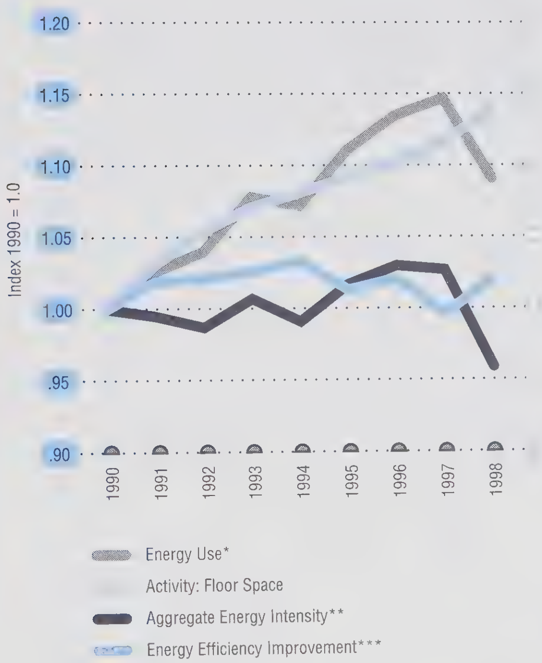
4.2 Trends in Energy Use

Figure 4.4 illustrates the trends in commercial sector energy use, aggregate energy intensity, activity and energy efficiency from 1990 to 1998.

During this period, energy use in Canada's commercial sector increased by 8.9 percent, or 77 petajoules (including street lighting). Activity in the sector increased by 13.8 percent during the same period, which is reflected in an increase of 64 million square metres in total floor space occupied.

Aggregate energy intensity decreased by 4.1 percent over this period, mostly because of changes in weather.

Figure 4.4: Commercial Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 (index 1990 = 1.0)



* Includes Street Lighting
** Excludes Street Lighting
*** This report presents an index of energy efficiency improvements while previous reports presented an index of the effects of energy efficiency on energy use.

Energy efficiency in the commercial sector improved by 2.0 percent from 1990 to 1998 (this improvement was accompanied by an unusually warm winter in 1998). Even though the 1998 winter was significantly warmer than usual, warmer than usual winter temperatures were also observed in 1990. In fact, the 1990 winter was 7.5 percent warmer than usual while the 1998 winter was 15.2 percent warmer. This means that the 1998 winter was 8.3 percent warmer than the 1990 winter, which explains why the impact of weather on energy use was lower than might be expected. Aggregate energy intensity decreased by 4.1 percent over this period, mostly because of changes in weather. Two distinct trends emerged: aggregate energy intensity declined between 1990 and 1994, despite colder weather relative to 1990, and increased from 1995 to 1997, largely as a result of colder weather.

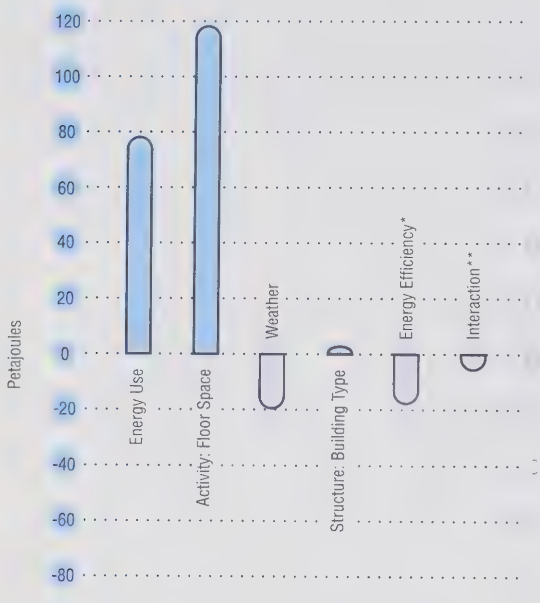
4.2.1 Factors Contributing to Changes in Energy Use

In this report, changes in energy use are attributed to four broad factors: changes in activity, changes in structure, changes in weather and changes in energy efficiency. The results of the OEE's factorization analysis for the commercial sector (shown in Figure 4.5) reveal significant variations in activity, weather and energy efficiency between 1990 and 1998, but only minor variations in structure (the mix of building types). Specifically, the analysis revealed that:

- had only activity changed over the period, energy use would have increased by 118 petajoules;
- had only weather changed over the period, energy use would have decreased by 20 petajoules;
- had only structure changed over the period, energy use would have increased by 3 petajoules; and
- had only energy efficiency changed over the period, energy use would have decreased by 18 petajoules.

A more detailed analysis follows.

Figure 4.5: Factors Influencing Growth in Commercial Energy Use, 1990–1998 (petajoules)



* Represents the effect of energy efficiency improvements on energy consumption.

** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

Figure 4.6: Annual Growth of Commercial Floor Space and RDP with a 3-Year-Lag, 1990–1998 (percent)

4.2.2 The Influence of Growth in Commercial Activity – The Activity Effect

Growth in commercial sector activity – the 13.8-percent increase in floor space noted earlier – was responsible for increasing energy use by 118 petajoules between 1990 and 1998. While notable, this increase was significantly less than the 31.9-percent growth rate recorded between 1984 and 1990.

A defining characteristic of the commercial real estate market is the lengthy amount of time required to conceive, design, obtain approval for and construct a commercial building in response to increased demand for space. This is illustrated in Figure 4.6, which shows a close correlation between the growth of real domestic product (RDP) in the commercial sector and growth in floor space three years later.

This phenomenon of the relationship to the GDP and the delay in developing buildings had a significant impact on the commercial sector in the period under review. Largely in response to economic growth in 1987 and 1988, new commercial floor space was added to the market in 1990 and 1991 – a period of significant economic downturn in Canada. As a result, the commercial sector began the 1990s with excess floor space. This surplus has gradually been reduced as the real estate market has adjusted to the new economic conditions.

Growth in commercial sector activity was responsible for increasing energy use by 118 petajoules between 1990 and 1998.

Changes in weather conditions reduced commercial energy use by 20 petajoules from 1990 to 1998.

4.2.3 The Influence of Fluctuations in Climatic Conditions – The Weather Effect

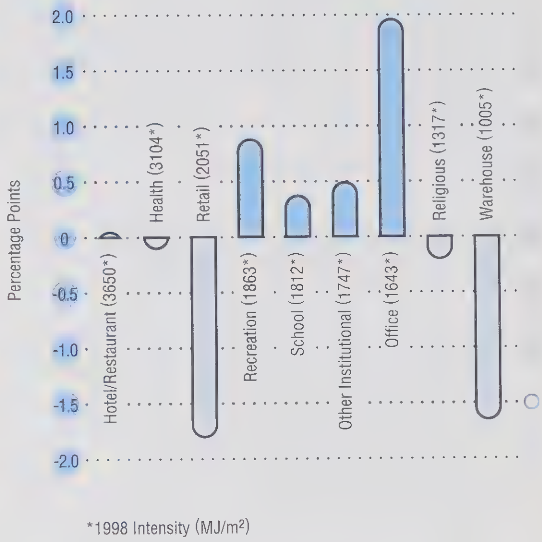
Changes in weather conditions reduced commercial energy use by 20 petajoules from 1990 to 1998, making weather the second most important factor affecting changes in commercial energy use during this period. The most notable effects of weather were as follows:

- space heating requirements declined, since the winter of 1998 was warmer than the winter of 1990 (heating degree-days[2] in 1998 were 8.4 percent below the 1990 level); and
- cooling requirements increased due to a warmer summer in 1998 than in 1990 (cooling degree-days[3] were 31.3 percent higher in 1998 than in 1990).

4.2.4 The Influence of Shifts in the Mix of Building Types – The Structure Effect

Changes in the distribution of floor space between different types of buildings resulted in a minor decrease in commercial energy use of 3 petajoules from 1990 to 1998. This decrease was, in fact, the result of many small changes in floor space allocation, as illustrated in Figure 4.7. For example, a 2.0 percentage points increase in the floor space occupied by offices was essentially offset by a 1.8 percentage points decline in retail space. Warehouses – the least energy-intensive type of commercial building – recorded the second largest decline in share of floor space, a drop of 1.7 percentage points.

Figure 4.7: Changes in Commercial Activity Shares by Building Type, 1990–1998 (percentage points)



4.2.5 The Influence of Variations in the Energy Efficiency of Commercial Energy Use – The Energy Efficiency Effect

Energy efficiency improvements in the commercial sector reduced secondary energy use by 18 petajoules from 1990 to 1998. Without these improvements, energy use in the sector would have increased by 11.1 percent, rather than the 8.9 percent noted on page 34.

The impact of energy efficiency improvements would have been much greater if the turnover of building stock[4] had not slowed in the period between 1990 and 1998 because new commercial buildings are generally more energy-efficient than existing buildings. As noted earlier, commercial floor space increased by only 13.8 percent in this period, compared to 31.9 percent from 1984 to 1990.

2 The number of degrees below 18°C in a day, added up for an entire year.

3 The number of degrees over 18°C in a day, added up for an entire year.

4 Turnover of building stock is when buildings are demolished and then replaced by newer ones.

Building energy efficiency is influenced by a number of factors – which are discussed in some detail in the following pages:

- the energy efficiency of the building itself and its heating, ventilation and air conditioning equipment;
- institutional factors; and
- the density of occupation.

The Energy Efficiency of the Building and Its Equipment

New heating equipment is significantly more energy efficient than the equipment manufactured even a few years ago. As a result, the construction of new buildings and building retrofits generally reduces the energy intensity of the building stock. In new buildings, efficiency improvements are primarily due to improved control systems and more efficient circulation and ventilation equipment. Boilers and furnaces have typically reached efficiency levels of about 85 percent, although condensing units can be as high as 92 percent efficient. Further efficiency improvements are possible but will require the use of more expensive materials to cope with increased flue gas condensation.

Changes in air conditioning equipment have largely been driven by the shift to non-CFC technologies. In large commercial applications, these new technologies can be 25 percent more energy efficient than conventional systems. However, since the cost of replacing existing equipment is prohibitive on the basis of energy savings alone, such improvements are generally achieved only in new construction or as part of major retrofits.

Changes in lighting technology, on the other hand, have led to energy efficiency gains in both new construction and existing buildings. One notable development is the move from T-12 to T-8 fluorescent tubes. Since this can be achieved without loss of lighting quality, the use of T-8 fluorescents can significantly reduce power densities for lighting with resulting energy savings of 20 percent to 25 percent.[5] Another important development is the increased use of electronic ballasts,[6] which are 15 percent to 40 percent more efficient than conventional ballasts. As well, incandescent lights can now often be replaced with compact fluorescent lamps, which again are 15 percent to 40 percent more efficient.

The impact of office equipment on a building's energy use is more difficult to determine. Despite dramatic growth in the use of office equipment (as witnessed by sales increases between 1990 and 1995 of 107 percent for desktop personal computers, 199 percent for UNIX-based technical workstations, 320 percent for laser printers and 98 percent for fax machines), two offsetting trends are clouding the assessment of energy use on a per unit basis. First, there is a clear move to more powerful computers with higher energy demands. However, this is being countered to some degree by the use of power management technologies that shift idle equipment to a low-power mode. This technology is now standard in desktop computers and is used in many copiers and some printers.

Electric motors are also a significant consumer of energy in commercial buildings. In recent years, motor efficiency has been improved through design enhancements and the use of higher quality materials and improved production processes. These new techniques reduce electrical losses from motors, which in turn make them more efficient. Depending on the size of the motor, energy-efficient models are

5 Marbek Resource Consultants, *Technology Profile Report: Fluorescent Lamps Linear T-12, T-10, T-8 Lamps*, Ottawa, Ontario, May 1995.

6 The ballast is the part of the fluorescent lighting unit that provides the necessary starting voltage and regulates the lamp's current during operation.

now 2 percent to 10 percent more efficient than standard motors. More than 50 percent of new motor sales and 5 percent of the existing motor stock in Canada are energy-efficient units.

Another development that is impacting energy efficiency in buildings is the growing use of advanced controls in both new construction and retrofit projects. For example, advances in air-handling systems (e.g., low-leakage dampers, economizers for free cooling, demand scheduling and improved air quality controls) have significantly increased energy efficiency in commercial buildings. In schools, the use of such technology can reduce ventilation energy consumption by up to 20 percent and heating energy consumption by about 7 percent. Service water heating controls can reduce energy use in buildings with high water consumption, such as school and hotels. Controls that automatically reduce lighting levels based on the availability of sunlight (multiple-step dimming) can reduce lighting energy consumption by up to 5 percent.

Institutional Factors

Institutional factors also affect overall building energy efficiency. The most notable development in the period under review was the emergence of energy service companies (ESCos), which not only design, implement and monitor energy efficiency retrofit projects but also finance them, recovering their investment through the resulting energy savings. This approach, in which the ESCo accepts the financial risk, has enabled commercial building owners – from the federal government to school boards to private sector companies – to undertake energy efficiency improvements that might not otherwise have been possible.

Occupation Density

The third factor affecting building energy efficiency is the density of occupation – the number of employees in the commercial sector per square metre of floor space. As a rule, the higher the occupation density of a given building, the higher its energy requirements and energy intensity.

As indicated in Figure 4.8, occupation density in the commercial sector declined by 1.7 percent from 1990 to 1998. This decline was primarily due to significant decreases in occupation density in 1991 and 1992, when there was excess commercial floor space and reduced employment in the sector. Occupation density increased steadily in subsequent years. This trend has been confirmed in most commercial building types.

Figure 4.8: Commercial Sector Employment per Floor Space, 1990–1998 (employment per thousands of square metres)

4.3 Trends in Greenhouse Gas Emissions

Greenhouse gas (GHG) emissions from the commercial sector increased by 13.1 percent from 1990 to 1998, primarily as a result of an 8.9-percent increase in energy use when street lighting is included (see Figure 4.10). The increase in GHG emissions is more important than the increase in energy use because of the change of fuel to generate electricity. This is the principal reason for the increase of greenhouse gas intensity of energy used by this sector – 3.9 percent from 55 tonnes per terajoule in 1990 to 57 tonnes per terajoule in 1998.

However, if emissions from electricity end-use were not included, the sector's GHG intensity of energy use would have decreased by 2.9 percent (see Figure 4.9).

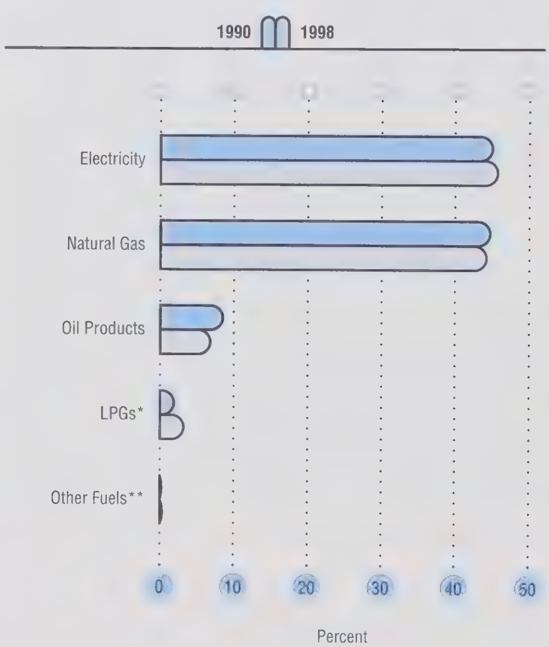
In 1998, electricity accounted for 45.7 percent of energy use in the commercial sector, so an increase in the GHG intensity of electricity generation has a major impact on total commercial emissions. In 1998, 49.5 percent of commercial GHG emissions were related to electricity. If the emissions from electricity generation were not attributed to the commercial sector, GHG emissions from the commercial sector would have increased by only 5.7 percent (not 13.1) and the GHG intensity of commercial energy use would have decreased by about 2.9 (as opposed to increased by 3.9 percent).

Figure 4.10 presents the commercial fuel shares in 1990 and 1998. Even if the natural gas and oil products shares decreased from 1990 to 1998, the global greenhouse gas intensity increased because of the higher shares of electricity and liquified petroleum gases (LPGs).

Figure 4.9: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Commercial Sector, 1990–1998 (percent)

ES: Electricity End-Use Emissions Scenario
NES: No Electricity End-Use Emissions Scenario

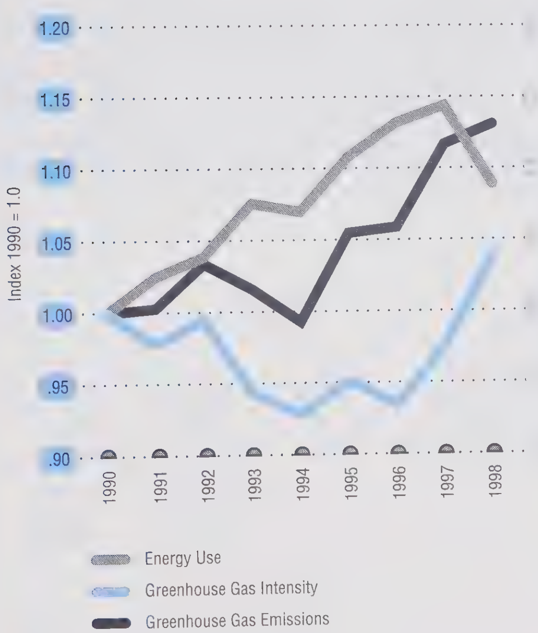
Figure 4.10: Commercial Energy Fuel Shares, 1990 and 1998 (percent)



* Liquefied Petroleum Gases
** Coal, Steam

As shown in Figure 4.11, during the 1990 to 1998 period, greenhouse gas emissions declined on two occasions – 1993 and 1994. The decline recorded in 1993 was due to reduced greenhouse gas intensity of energy use. The decline noted in 1994 was the result of a combination of reduced energy use and reduced greenhouse gas intensity. In 1996, the growth in emissions was offset somewhat by reduced greenhouse gas intensity.

Figure 4.11: Commercial Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, 1990–1998 (index 1990 = 1.0)



Greenhouse gas emissions from the commercial sector increased by 13.1 percent from 1990 to 1998, primarily as a result of an 8.9 percent increase in energy use when street lighting is included.

4.4 The Data Situation

Of the five sectors of the economy reviewed in this report, the commercial sector has the most significant data limitations in the area of energy use.

Data on aggregate commercial energy use are published by Statistics Canada under the commercial and other institutional and public administration categories. Commercial energy use by building type and by end-use are then estimated by the OEE, using NRCan's commercial energy end-use model. A key variable in this estimation is floor space, which is used as an approximation for commercial activity. Since there are few reported data regarding commercial floor space, estimates are made based on investment flows and average construction costs. In 1997, floor space estimates were benchmarked against provincial data from surveys and audits.

Energy use data in the commercial sector is not quantified through a data collection exercise – it is essentially the residual of energy use not accounted for in the industrial, residential, transportation and agricultural sectors. To address this problem, a study commissioned by NRCan in 1996 recommended the development of two related surveys to collect energy use data for the commercial sector.[7]

The first survey will collect energy intensity information at the building level, while the second survey will collect energy intensity data for end-uses in large buildings. The proposed data collection strategy has been pilot tested, with the results detailed in a report entitled *Commercial Building Energy Use Survey Pilot Study: Summary Report*. The survey to address energy intensity at the building level, currently known as the Commercial/Institutional Building Energy Use Survey, was in the development and testing phase at the time of writing. This will be followed by development of the energy intensity end-use survey. Data collection is planned for later in 2000.

7 ARC Applied Research Consultants and Engineering Interface Ltd., *A Detailed Strategy for Commercial Sector Data Collection in Canada*, June 1997.

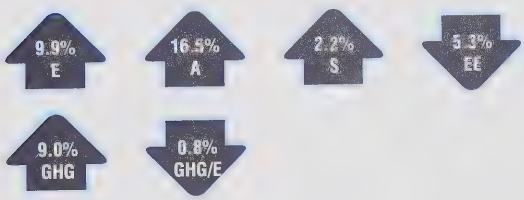
Industrial Sector

Definition: The Canadian industrial sector includes all manufacturing industries, mining, forestry and construction.

Highlights

- From 1990 to 1998, energy use (E) in Canada's industrial sector increased by 9.9 percent, or 272 petajoules. This growth was the result of:
    - a 16.5 percent increase in activity (A) (measured by physical units of output and Gross Domestic Product (GDP). Had activity changed over the period, and all other factors remained constant, energy use would have increased by 455 petajoules.
    - changes in structure (S), specifically a shift of activity toward more energy-intensive industries. Had all other factors remained constant and only structure changed, energy use would have increased by 62 petajoules.
    - a 5.3 percent improvement in energy efficiency (EE represents the energy efficiency effect on energy use). If only energy efficiency had changed over the period, while all other factors remained constant, energy use would have decreased by 145 petajoules.
- Greenhouse Gas (GHG) emissions from the industrial sector increased by 9.0 percent from 1990 to 1998, while the GHG intensity (GHG/E) of energy use decreased by 0.8 percent.
- Five industries – upstream mining, petroleum refining, iron & steel, newsprint and primary production of aluminum – accounted for more than 50 percent of the sector GHG emissions in 1998. Upstream mining, primary production of aluminum and wood industries were the only industries to increase their share of emissions by more than 1 percentage point over the 1990 to 1998 period.

The Energy/Emissions Barometer – Industrial Sector



5.1 Overview – Energy Use and Greenhouse Gas Emissions

In 1998, energy used by the industrial sector totalled 3027 petajoules, or about 39.5 percent of secondary energy demand in Canada. GHG emissions from industrial energy use totalled 155 megatonnes of carbon dioxide (CO_2) equivalent, or about 34.4 percent of GHG emissions from secondary energy use. From this amount, 152 megatonnes (about 98 percent) were from emissions of CO_2 while the remaining 2 percent were from emissions of methane (CH_4) and nitrous oxide (N_2O).

In the industrial sector, energy is used primarily to produce heat, to generate steam or as a source of motive power. For example, coal is one of the types of energy used by the cement industry to heat its cement kilns, many industries use natural gas to fuel their boilers for steam generation and electricity to power motors for pumps and fans.

To better understand the factors underlying the change in energy use that occurred during the review period, it is useful to look at activities in previous years.

When industry entered the 1990s, it had just been through six years of significant growth. From 1984 to 1989, investment in machinery and equipment relative to the total stock of machinery and equipment increased steadily. This reflects the fact that in a period of growth, industry operates at higher capacity utilization rates and will often add capacity. As new capacity is generally more energy-efficient, industrial intensity decreased by 4.5 percent between 1984 and 1990.

Between 1990 and 1992, industrial activity declined by 6.1 percent as capacity utilization rates declined and investment in machinery and equipment decreased by about 31 percent. As is typical of periods of decelerating economic activity, energy use declined at a slower pace than activity because of the need to meet fixed energy requirements. As a result, energy efficiency decreased by 3.2 percent.

After 1992, the Canadian economy began to recover, and investments in machinery and equipment in the manufacturing and mining sectors increased by about 45 percent between 1992 and 1998, while the stock of machinery and equipment increased by 27 percent.

As table 5.1 indicates, the refined petroleum and coal products industries (SIC 36) are the industries for which this ratio increased the most rapidly between 1992 and 1998. Refined petroleum and coal products industries' investments in machinery and equipment as a share of total stock were almost three times higher in 1998 compared with 1992.

Over the same period 1992 to 1998, total industry energy use grew by 11.2 percent while aggregate activity increased by 22.3 percent. Industrial energy efficiency improved by 8.5 percent.

Figure 5.1 illustrates a notable characteristic of the industrial sector: those industries that record the highest levels of activity do not necessarily consume the most energy. Together, the construction, food, transportation equipment, electrical and electronics products, and other manufacturing[1] industries were responsible for 46.7 percent of 1998 industrial activity (measured as GDP) but used only 10.1 percent of industrial energy use. On the other hand, the pulp, newsprint, petroleum refining, and iron and steel industries combined were responsible for only 5.4 percent of industrial activity, but for 40.2 percent of industrial energy use.

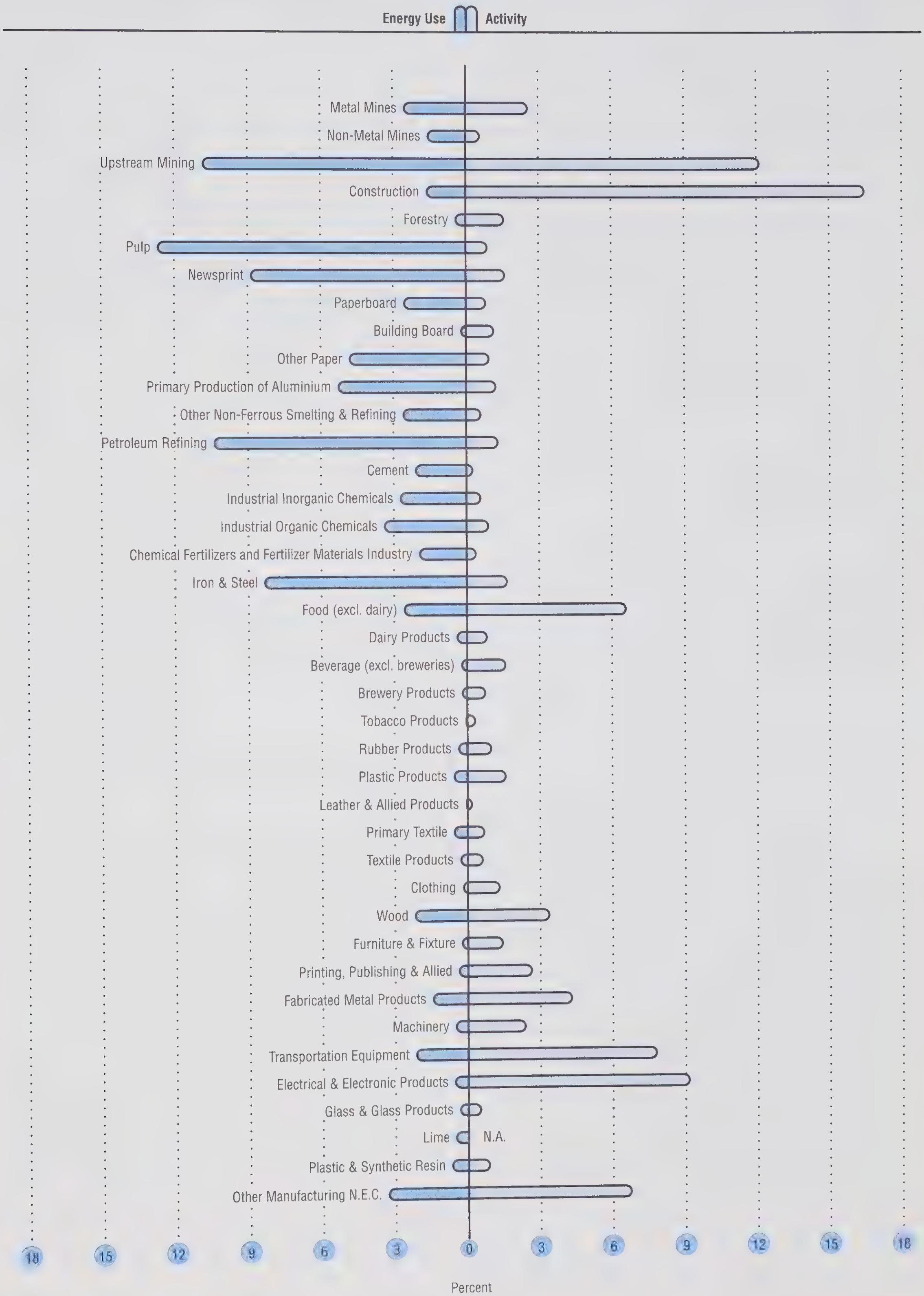
Table 5.1: Machinery and Equipment Investments as a Share of Total Stock of Machinery and Equipment, 1992–1998 (percent)

Industries	1992	1993	1994	1995	1996	1997	1998
Mining (SIC 6)	6.0	7.6	8.5	13.8	13.3	13.1	10.6
Food (SIC 10)	11.0	9.6	8.5	8.8	10.0	8.6	8.3
Beverage (SIC 11)	10.6	9.7	8.4	8.3	6.2	7.7	11.1
Tobacco Products (SIC 12)	-	-	-	-	-	-	15.4
Rubber Products (SIC 15)	12.9	8.1	5.9	7.8	6.1	11.0	11.1
Plastic Products (SIC 16)	12.3	11.6	13.9	13.6	13.9	10.0	12.1
Primary Textile (SIC 18)	8.3	10.3	9.7	9.0	15.7	11.9	10.1
Textile Products (SIC 19)	9.7	13.3	14.0	6.9	9.4	9.3	12.1
Clothing (SIC 24)	14.1	10.0	17.4	10.4	11.0	13.5	11.0
Wood (SIC 25)	7.1	10.0	13.9	17.6	11.8	10.0	8.6
Furniture & Fixture (SIC 26)	12.8	14.5	13.9	15.2	16.2	21.2	17.8
Paper & Allied Products (SIC 27)	5.7	4.9	4.6	6.6	5.8	5.2	4.4
Printing, Publishing & Allied Industries (SIC 28)	11.5	11.5	9.9	8.1	11.7	10.5	12.0
Primary Metal Industries (SIC 29)	5.5	3.8	2.3	4.0	5.3	7.7	6.6
Fabricated Metal Products Industries (SIC 30)	8.6	9.2	11.1	13.3	16.8	14.7	13.4
Machinery Industries (SIC 31)	13.4	16.1	19.5	19.4	20.1	14.9	15.3
Transportation Equipment (SIC 32)	14.4	15.3	15.0	14.4	14.0	15.9	13.6
Electrical and Electronic Products (SIC 33)	11.6	13.5	13.2	11.8	13.5	14.5	19.6
Non-Metallic Mineral Products (SIC 35)	4.8	5.0	7.6	8.0	7.2	7.4	11.9
Refined Petroleum and Coal Products Industries (SIC 36)	5.7	3.9	3.3	4.4	4.6	6.2	14.3
Chemical and Chemical Products Industries (SIC 37)	8.1	7.9	5.4	4.8	5.6	6.5	11.9
Other Manufacturing Products Industries (SIC 39)	6.0	6.4	4.4	2.8	5.5	4.5	3.4
Total – Manufacturing and Mining Sectors	8.1%	8.0%	7.7%	8.7%	8.8%	9.1%	9.4%

Source: Statistics Canada, *Private and Public Investments in Canada, 1992–1998.* Ottawa. January 2000 (CANSIM)

1 Industries that were not classified in any of the other industries analyzed.

Figure 5.1: Distribution of Energy Use and Activity (as measured by GDP) by Industry, 1998 (percent)



For this report, the OEE has divided the industrial sector into 40 distinct industries. This chapter focuses on:

- industries that had significant increases in their level of activity;
- industries that achieved significant energy efficiency improvements; and
- industries that used significant amounts of energy.

As well, readers should be advised that a number of changes have been made since the last report (*Energy Efficiency Trends in Canada – An Update,* January 2000). For an explanation of these changes, and other methodological improvements made in the last report, see the box entitled "Discussion of Methodology" on page 47.

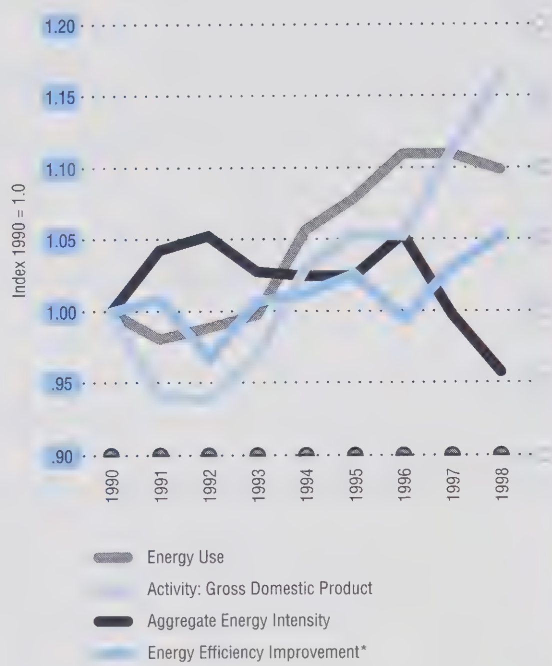
5.2 Trends in Energy Use

Figure 5.2 illustrates the trends in industrial sector energy use, aggregate energy intensity, activity and energy efficiency from 1990 to 1998.

During this period, energy use in Canada's industrial sector increased by 9.9 percent, or 272 petajoules, while aggregate activity in the sector (GPD only) increased by 14.7 percent.

Energy efficiency in the industrial sector improved by 5.3 percent from 1990 to 1998. This differs from aggregate energy intensity, which decreased by 4.2 percent. The discrepancy between these two indicators arises because the aggregate energy intensity indicator captures changes in activity and structure. Also, the energy efficiency indicator is calculated using a mix of physical units of output and GDP while the aggregate indicator is calculated using only GDP to represent activity.

Figure 5.2: Industrial Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 (index 1990 = 1.0)



*This report presents an index of energy efficiency improvements while previous reports presented an index of the effects of energy efficiency on energy use.

Those industries that record the highest levels of activity do not necessarily consume the most energy.

5.2.1 Factors Contributing to Changes in Energy Use

Changes in industrial energy use over the review period are attributed to three broad factors: changes in activity, changes in structure (the mix of economic activity among industries) and changes in energy efficiency. The OEE's factorization analysis for the industrial sector reveals that growth in industrial energy use between 1990 and 1998 was due mainly to growth in activity, although changes in structure also had an impact (see Figure 5.3). These upward pressures on energy use were partly offset by improvements in energy efficiency.

Figure 5.3: Factors Influencing Growth in Industrial Energy Use, 1990–1998 (petajoules)

* Represents the effect of energy efficiency improvements on energy consumption.

** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

Specifically, the analysis revealed that:

- had only activity changed over the period, while structure and intensity remained constant, energy use would have increased by 455 petajoules;
- had only structure changed over the period, while activity and intensity remained constant, energy use would have increased by 62 petajoules; and
- had only energy efficiency changed over the period, while activity and structure remained constant, energy use would have decreased by 145 petajoules.

Table 5.2 provides data on energy use, activity and energy intensity trends for all 40 industries analysed by the OEE and the industrial sector as a whole. A more detailed analysis of the impact of changes in activity, structure and energy efficiency on industrial energy use follows.

A Discussion of Methodology

The following is a brief explanation of recent changes in how the OEE (Office of Energy Efficiency) analyses energy efficiency trends in the industrial sector.

Activity Indicators

Changes in activity levels are a fundamental part of the OEE's analysis of energy efficiency trends. In the case of the industrial sector, activity can be measured in two basic ways – as economic output or as physical output. Measures of physical units of production are considered to be more meaningful and have been used by the OEE whenever possible since the last report. When physical output measures were not available – for example, when an industry's products are too diverse to allow the use of a single measure of physical output for the industry – GDP has been used to measure economic output.

It should be noted that the OEE considered using Gross Output (GO), a measure of the value of shipments made by an industry, rather than GDP as a measure of economic output. While GO can be an excellent activity indicator within a specific industry, it can not be summed across industries. GDP is a better aggregate measure; it measures the valued added to an output by any given industry and thus can be summed across industries. However GDP for a specific industry can be affected by business cycle changes in the broader economy.

In order to have the flexibility to use both physical units of production and GDP as activity indicators, several improvements were made to the OEE's factorization methodology. These are explained in detail in Appendix C.

Analysis by Industry as Opposed to Sectors

Prior to 1997, the OEE's factorization analysis was done on the basis of 10 industry sectors, using GDP as the measure of economic activity. However, for the update report published in January 2000, which reviewed energy efficiency trends for the period from 1990 to 1997, the analysis was further broken down into 39 specific industries, using both GDP and physical units of production to measure economic activity. In the current report, a 40th industry has been added – the dairy products industry. In this report, physical units of production were available for three more industries: rubber products, metal mines and non-metal mines industries. The analysis was done taking these new data into consideration.

This level of analysis is possible as a result of work initiated by the OEE and undertaken by the Canadian Industrial Energy End-Use Data and Analysis Centre (CIEEDAC) at Simon Fraser University (Burnaby, British Columbia), in collaboration with the Canadian Industry Program for Energy Conservation (CIPEC).

5.2.2 The Influence of Growth in Industrial Activity – The Activity Effect

The activity effect measures how energy consumption would have changed if the level of production (measured by GDP or physical units) had changed and all other factors had remained constant.

As noted in the box on page 47, there are different ways to measure economic activity in the industrial sector. For the purposes of this analysis:

- "**aggregate activity**" is measured by total industrial GDP, which increased by 14.7 percent between 1990 and 1998. Had aggregate activity been used as the measure of activity in the factorization analysis, there would have been a 406-petajoule increase in energy use.
- "**activity**" is measured using an index derived from a mix of GDP and physical units of production (where available). This measure of production is used in the factorization analysis for this report. The analysis attributes 455 petajoules of the increase in energy use to growth in activity.

The factorization analysis decomposes the 455-petajoule increase in energy use, due to the activity effect, between the 40 industries analysed. The factorization results, presented in Table 5.3, show the six industries that contributed most significantly to the increase in the activity.

Table 5.2: Summary of Trends in Energy Use, Activity and Energy Intensity in the Industrial Sector, 1990 to 1998 (percent change)

	Energy Use	Activity	Energy Intensity
Total Industrial	9.9	14.7	-4.2
Metal Mines *	-15.8	-9.5	-7.0
Non-Metal Mines *	16.0	17.9	-1.6
Upstream Mining	55.5	42.1	9.4
Construction	-27.7	-12.8	-17.2
Forestry	61.0	-16.5	92.8
Pulp *	7.3	36.2	-21.2
Newsprint *	1.8	-4.2	6.3
Paperboard *	34.0	35.5	-1.2
Building Board *	131.5	174.6	-15.7
Other Paper *	39.4	56.3	-10.8
Primary Production of Aluminum *	40.1	52.5	-8.1
Other Non-Ferrous Smelting & Refining	12.6	10.9	1.5
Petroleum Refining*	-6.2	7.2	-12.5
Cement *	6.4	15.0	-7.4
Industrial Inorganic Chemicals *	11.1	1.7	9.3
Industrial Organic Chemicals	-11.5	-3.8	-8.0
Chemical Fertilizers and Fertilizer Materials *	74.4	5.5	65.3
Iron & Steel	14.8	21.6	-5.5
Food (excluding dairy)	5.8	19.7	-11.6
Dairy Products	1.4	1.5	-0.1
Beverage (excluding brewery)	-27.1	15.2	-36.7
Brewery Products *	-20.7	1.8	-22.1
Tobacco Products	-19.6	-8.6	-12.1
Rubber Products *	15.6	97.9	-41.6
Plastic Products	36.3	44.7	-5.8
Leather & Allied Products	-5.2	-28.6	32.8
Primary Textile	-6.6	20.8	-22.7
Textile Products	24.3	4.3	19.2
Clothing	-0.1	-9.0	9.8
Wood	75.3	18.0	48.6
Furniture & Fixture	31.7	57.7	-16.5
Printing, Publishing & Allied	24.8	-21.5	58.9
Fabricated Metal Products	57.4	13.7	38.4
Machinery	17.3	12.5	4.3
Transportation Equipment	23.4	46.0	-15.5
Electrical and Electronic Products	-12.7	91.9	-54.5
Glass & Glass Products	-20.8	53.8	-48.5
Lime *	5.3	23.4	-14.7
Plastic & Synthetic Resin *	25.0	42.7	-12.4
Other Manufacturing N.E.C.	-43.1	-0.9	-42.6

* Physical units of production were used as the measure of activity for these sub-sectors
For the remaining sub-sectors, gross domestic product (GDP) was used.

Table 5.3: Activity Effect: Main Industries Responsible for the Variation in Activity, 1990–1998

Industry	Activity Effect on Total Industrial Energy Use (petajoules)	Contribution to the Change in Activity (percent)
Pulp	59	13
Petroleum Refining	55	43
Newsprint	43	10
Iron & Steel	36	8
Upstream Mining	35	8
Other Manufacturing n.e.c.	29	6

Table 5.2, presented earlier in this chapter, reveals that several other industries experienced dramatic growth in activity between 1990 and 1998, although the impact of this growth on total industrial energy use was less notable. Activity in the:

- building board industry increased by 174.6%,
- rubber products industry increased by 97.9%,
- furniture & fixture industry increased by 57.7%,
- other paper industries increased by 56.3%,
- glass & glass products industry increased by 53.8%, and
- primary production of aluminum increased by 52.5%.

Despite the impressive growth rates in their activity, these six industries accounted for only 11.2 percent of total industrial energy use and 6.2 percent of aggregate activity in 1998.

5.2.3 The Influence of Shifts in the Distribution of Industrial Activity – The Structure Effect

Changes in structure – specifically a shift of economic activity toward more energy-intensive industries – was responsible for 62 petajoules of increased energy use between 1990 and 1998. Figure 5.4 illustrates this change: the sector's 20 most energy-intensive industries increased their total share of activity by about 2 percentage points.

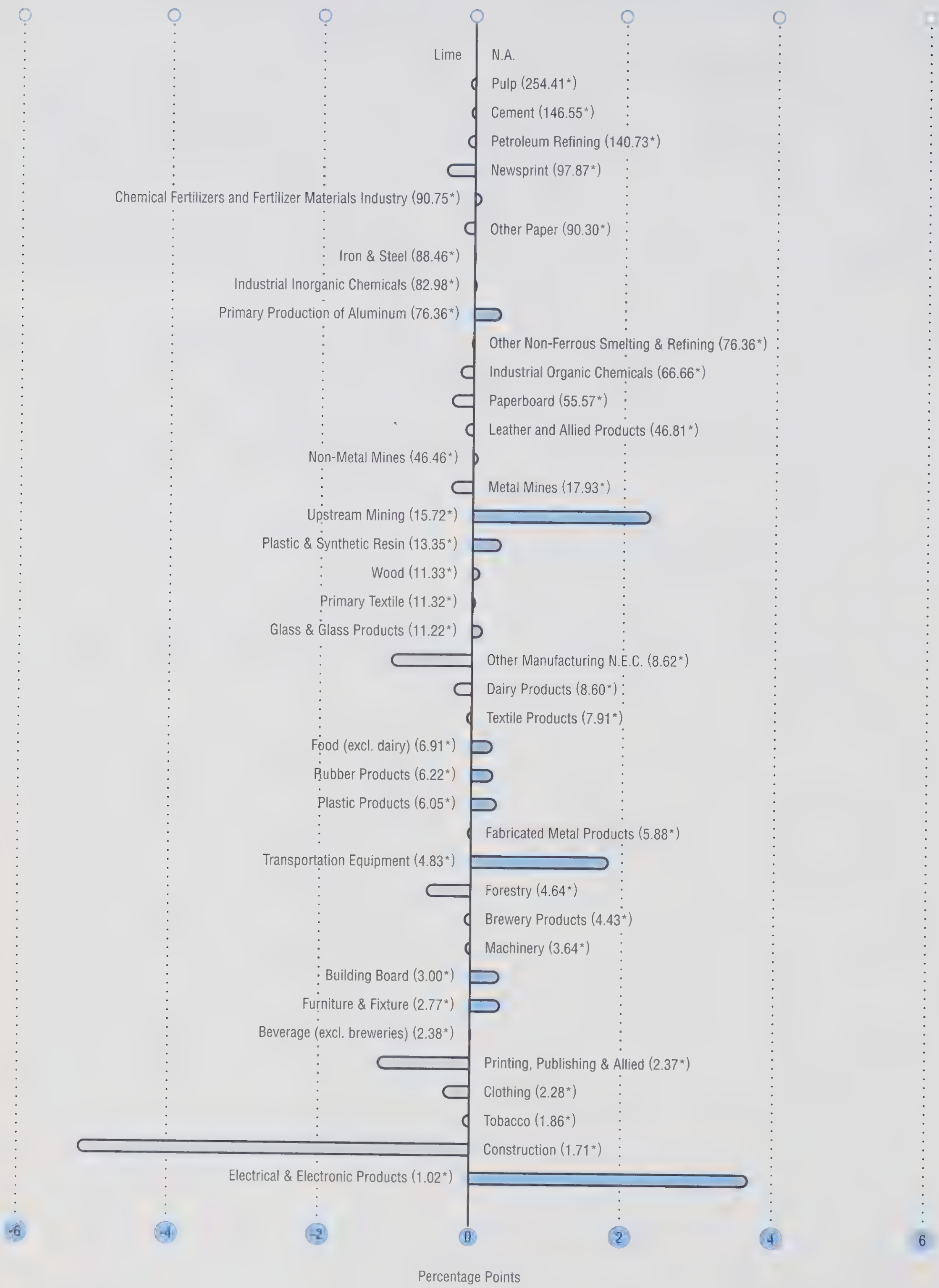
Four of the most energy-intensive industries – the chemical fertilizers and fertilizer materials, iron and steel, industrial inorganic chemicals and aluminum industries – together increased their share of GDP by about 0.5 percentage point. On the other hand, construction, which is one of the least energy intensive, decreased its share of GDP by more than 5 percentage points.

5.2.4 The Influence of Variation in the Energy Efficiency of Industrial Energy Use – The Energy Efficiency Effect

Energy efficiency in the industrial sector improved by 5.3 percent from 1990 to 1998. Without this improvement, industrial energy use would have been 145 petajoules higher in 1998 than actual levels.

On an industry-by-industry basis, several sectors achieved significant energy efficiency gains while energy efficiency decreased in other sectors during the review period. Table 5.4 shows the change in energy efficiency and its impact on energy use for industries having experienced the largest change in their energy efficiency (increase or decrease) over the review period.

Figure 5.4: Changes in Sectoral Shares of Industrial Activity, 1990–1998 (percentage points)



*Energy Intensity (MJ/$86)

Table 5.4: Variation in Energy Efficiency for Selected Industries, 1990–1998

Industry	Change in energy use 1990–1998 (petajoules)	Change in energy efficiency 1990–1998 (percent)	Energy Efficiency Effect on Energy Use by Industry (petajoules)
Electrical & Electronic Products	-2	55	-10
Glass & Glass Products	-3	49	-6
Beverage (excluding breweries)	-2	37	3
Rubber Products	1	42	-4
Leather & Allied Products	marginal	-33	1
Printing, Publishing & Allied Products	2	-59	11
Chemical Fertilizers & Fertilizer Materials	25	-65	22
Forestry	5	-93	7

The four industries that experienced the most significant improvement in their energy efficiency represent 12.2 percent of industrial GDP but only 1.4 percent of total energy use. On the other hand, the four industries presented in the table (showing deterioration of their energy efficiency) represent only 4.7 percent of industrial GDP and 2.7 percent of total energy use.

5.3 Industry-by-Industry Analysis

This section of the chapter provides data on several industries that experienced significant changes in activity, energy use and/or energy efficiency in the review period.

At the industry-by-industry level, the factorization analysis measures the structure effect in two different ways. For the five industries that have sub-industries (i.e., the metal mines, non-metal mines, food, wood and transportation equipment industries), changes in structure were measured as shifts of activity between their sub-industries. For the remaining 35 industries analysed, shifts in the type of fuel used by the industry (fuel switching) were measured. Fuel switching measures the impact of a shift of fuel on energy use. For example, wood waste and pulping liquor have lower energy contents than natural gas. Moving from natural gas to wood waste, while keeping the same level of production, will result in an increase in energy demand. This increase is measured by the fuel switching effect.

5.3.1 Beverage Industry (excluding breweries)

Energy Use: decreased by 27%
Activity Effect: increased energy use by 15% (as measured by GDP)
Energy Efficiency Effect: decreased energy use by 37%
Fuel Switching Effect: marginal

Several factors influenced energy efficiency in the beverage industry. For example, the volume of packaging used in the manufacture and distribution of soft drinks was reduced by 67 percent between 1988 and 1998. This was achieved in part by substituting steel cans and glass bottles with light polyethylene terephthalate (PET) bottles and aluminum cans. As well, today's PET containers are 21-percent lighter, and aluminum cans are 65-percent lighter, than their counterparts of 20 years ago. Lighter containers require less storage space and less energy for on-site transportation, both of which help to reduce the energy use per unit of output.[2]

2 Office of Energy Efficiency, *Canadian Industry Program for Energy Conservation 1997/1998 Annual Report*, Ottawa, 1999.

5.3.2 Brewery Products Industry

Energy Use: decreased by 21%
Activity Effect: increased energy use by 2% (as measured by physical units of production)
Energy Efficiency Effect: decreased energy use by 21%
Fuel Switching Effect: decreased energy use by 1%

The brewery products industry has undertaken many activities with the goal of improving energy efficiency. As a result, energy use substantially decreased despite an increase in the activity. For example, older equipment has been replaced with newer, more energy-efficient pasteurizers and higher-efficiency motors. As well, the industry has indicated that it will calibrate boiler instrumentation and combustion controls more frequently, which in turn improves their efficiency.[3]

5.3.3 Electrical and Electronic Products Industry

Energy Use: decreased by 13%
Activity Effect: increased energy use by 92% (as measured by GDP)
Energy Efficiency Effect: decreased energy use by 55%
Fuel Switching Effect: marginal

The electrical and electronic products industry grew rapidly between 1990 and 1998; as noted above, its GDP almost doubled during the review period. The industry was responsible for 9.1 percent of industrial aggregate activity in 1998 (compared to 5.5 percent in 1990), but accounted for less than 1 percent of total industrial energy use.

This is a highly advanced, extremely competitive and export-oriented industry. Its constant focus on technological innovation is a driving force behind energy efficiency improvements.

5.3.4 Iron and Steel Industry

Energy Use: increased by 15%
Activity Effect: increased energy use by 22% (as measured by physical units of production)
Energy Efficiency Effect: decreased energy use by 5%[4]
Fuel Switching Effect: marginal

The energy efficiency improvement in this sector helped offset the activity effect on energy use. The move to electric arc furnaces for steel production is the main contributor to the improvement in energy efficiency. Electric arc furnaces consume mostly scrap metal and require only 13 percent of the energy used by an equivalent integrated steel mill.[5]

5.3.5 Other Paper Industries

Energy Use: increased by 39%
Activity Effect: increased energy use by 56% (as measured by physical units of production)
Energy Efficiency Effect: decreased energy use by 22%
Fuel Switching Effect: increased energy use by 12%

The "other paper" industries (including toilet paper, paper towel, etc.) is the second most energy-intensive industry in the pulp & paper sector. The "other paper" energy use accounts for about 17 percent of the pulp & paper sector and 5 percent of total industrial energy use in 1998. While activity in the "other paper" industry increased significantly during the review period, the activity effect on energy use was partly offset by energy efficiency improvements.

3 Office of Energy Efficiency, *Canadian Industry Program for Energy Conservation 1997/1998 Annual Report*, Ottawa, 1999.

4 The Canadian Industry Program for Energy Conservation (CIPEC) has adjusted the iron and steel industry's 1990 energy and production figures to take into account a six-month strike in 1990. No such adjustment is made here, which accounts for the discrepancy between this report and the CIPEC *1997/1998 Annual Report*, Ottawa, 1999.

5 Office of Energy Efficiency, *Canadian Industry Program for Energy Conservation 1997/1998 Annual Report*, Ottawa, 1999.

As it is the case for the pulp industry, much of the energy efficiency improvement achieved in the "other paper" industries can be attributed to the upgrading of auxiliary equipment and motors and to the increased use of recycled paper. However, energy efficiency improvements were partly offset by changes in the fuel mix within the industry, which was responsible for increased energy use of 12 percent.

Most of the fuel switching effect is due to the growing use of biomass (solid wood waste and waste pulping liquor) and steam, which accounted for about 68 percent of total energy consumption in 1998, compared to 33 percent in 1990. Biomass has less energy content than other fuels, so more biomass is required to achieve the same level of energy output. On the other hand, biomass and steam are considered to add no net CO_2 emissions, which helped to curb emissions from the "other paper" industries.

5.3.6 Petroleum Refining Industry

Energy Use: decreased by 6%
Activity Effect: increased energy use by 7% (as measured by physical units of production)
Energy Efficiency Effect: decreased energy use by 12%
Fuel Switching Effect: marginal

The petroleum refining industry accounts for about 10 percent of total industrial energy use. Energy efficiency improvements in the industry were due to a number of factors. The petroleum refining industry has undertaken extensive rationalization over the past two decades, leading to many smaller, less-efficient refineries being closed thus increasing utilization rates (averaging close to 92 percent in 1998 based on rated capacity, compared to 89 percent in 1997). Also, refineries are now using advanced computer control technology to reduce energy requirements with a focus on better equipment operation and upgrading.[6]

5.3.7 Primary Production of Aluminum Industry

Energy Use: increased by 40%
Activity Effect: increased energy use by 53% (as measured by physical units of production)
Energy Efficiency Effect: decreased energy use by 8%
Fuel Switching Effect: marginal

New production capacity was installed at four of the 11 aluminum smelters in Canada between 1990 and 1998, contributing to a 53-percent increase in activity across the industry. Furthermore, significant new investments were made in this industry during the review period to meet growing world demand for aluminum. As mentioned earlier in this chapter, in a period of increasing investments, efficiency gains generally occur at a faster pace.

Energy efficiency improvements in this industry were the result of:

- the introduction of new equipment (a move from the Horizontal Stud Soderberg technology to the Centre-Worked Prebake technology helped the industry increase production with only a small increase in energy use);
- increased employee awareness and involvement in energy-related issues; and
- improved operating practices, including the use of computer process control for operational stability.

6 Office of Energy Efficiency, *Canadian Industry Program for Energy Conservation 1997/1998 Annual Report*, Ottawa, 1999.

5.3.8 Primary Textile Industry

Energy Use: decreased by 7%
Activity Effect: increased energy use by 21% (as measured by GDP)
Energy Efficiency Effect: decreased energy use by 22%
Fuel Switching Effect: decreased energy use by 16%

Liberalization of international and inter-provincial trade, while boosting the primary textile industry's GDP, is putting increased pressure on textile producers to remain competitive. For this and other reasons, the industry has undertaken a number of aggressive programs to improve energy efficiency and reduce energy consumption.

Through these programs, the industry was able to reduce its use of energy during a period of economic growth. If not for growth in activity, the combination of energy efficiency improvements and changes in the mix of fuels (a shift toward electricity at the expense of the other fuels, which further reduced the demand for energy) would have cut energy use by about 5 petajoules (38 percent) over the review period.

5.3.9 Pulp Industry

Energy Use: increased by 7%
Activity Effect: increased energy use by 36% (as measured by physical units of production)
Energy Efficiency Effect: decreased energy use by 21%
Fuel Switching Effect: decreased energy use by 1%

Within the pulp & paper sector, the pulp industry is the most energy intensive. This industry's energy use accounted for 44 percent of the pulp & paper sector and for 13 percent of the total industrial energy use in 1998.

Most of the industry's energy efficiency improvements occurred between 1990 and 1996, as a result of a drive to upgrade auxiliary equipment and motors. As well, the industry has increased its use of mechanical pulping technologies at the expense of chemical pulping technologies – the latter being more energy intensive. In fact, mechanical pulping accounted for 16.2 percent of production in 1998 compared to 12.9 percent in 1990.

The increased use of recycled paper technology is another factor that influenced the improvement in energy efficiency. Making pulp using recycled fibres requires less energy than pulp made using virgin fibres.

5.3.10 Rubber Products Industry

Energy Use: increased by 16%
Activity Effect: increased energy use by 98% (as measured by physical units of production)
Energy Efficiency Effect: decreased energy use by 41%
Fuel Switching Effect: marginal

The important increase in activity in the rubber products industry has been in good part offset by its energy efficiency improvement. Three main factors drove energy efficiency improvements in the rubber products industry. First, the rationalization of the North American industry: companies with multiple plants restructured their operations (individual plants produce a narrower range of products but in higher volumes) to take advantage of economies of scale. Second, the automotive industry – the main user of rubber products – has grown very rapidly since 1994. There has been increasing pressure from this industry to improve the quality and lower the cost of rubber products. Finally, an undervalued Canadian dollar favoured increased production.[7]

Greenhouse gas (GHG) emissions from the industrial sector increased by 9.0 percent from 1990 to 1998, primarily as a result of a 9.9 percent increase in energy use.

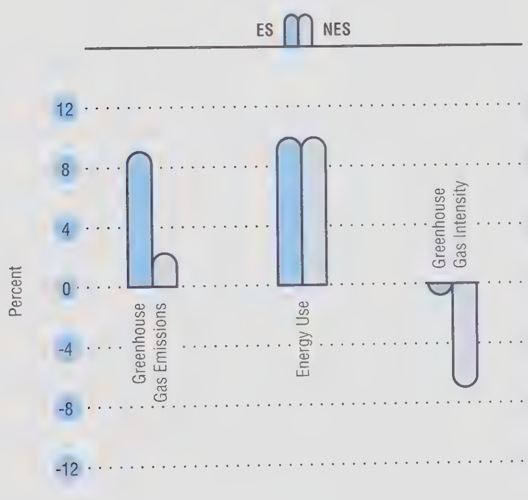
7 Office of Energy Efficiency, *Canadian Industry Program for Energy Conservation 1997/1998 Annual Report*, Ottawa, 1999.

5.4 Trends in Greenhouse Gas Emissions [8]

Greenhouse gas (GHG) emissions from the industrial sector increased by 9.0 percent from 1990 to 1998, primarily as a result of a 9.9-percent increase in energy use (see Figure 5.5). The GHG intensity of the energy used by this sector declined marginally (0.8 percent), from 51.7 tonnes per terajoule in 1990 to 51.3 tonnes per terajoule in 1998.

However, with emissions from electricity[9] end-use omitted, the sector's GHG intensity would have declined by 7.0 percent. GHG emissions from electricity generation increased sharply in the latter part of the review period, due to changes in the types of fuel used to generate electricity.

Figure 5.5: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Industrial Sector, 1990–1998 (percent)



ES: Electricity End-Use Emissions Scenario
NES: No Electricity End-Use Emissions Scenario

Electricity accounts for more than 25 percent of energy use in the industrial sector, so an increase in the GHG intensity of electricity generation has a major impact on total industrial emissions. In 1998, more than 30 percent of industrial GHG emissions were related to electricity. If the emissions from electricity generation were not attributed to the industry, GHG emissions from the industrial sector would have increased by only 2.2 percent (not 9.0 percent) and the GHG intensity of industrial energy use would have decreased by about 7.0 percent (as opposed to 0.8 percent).

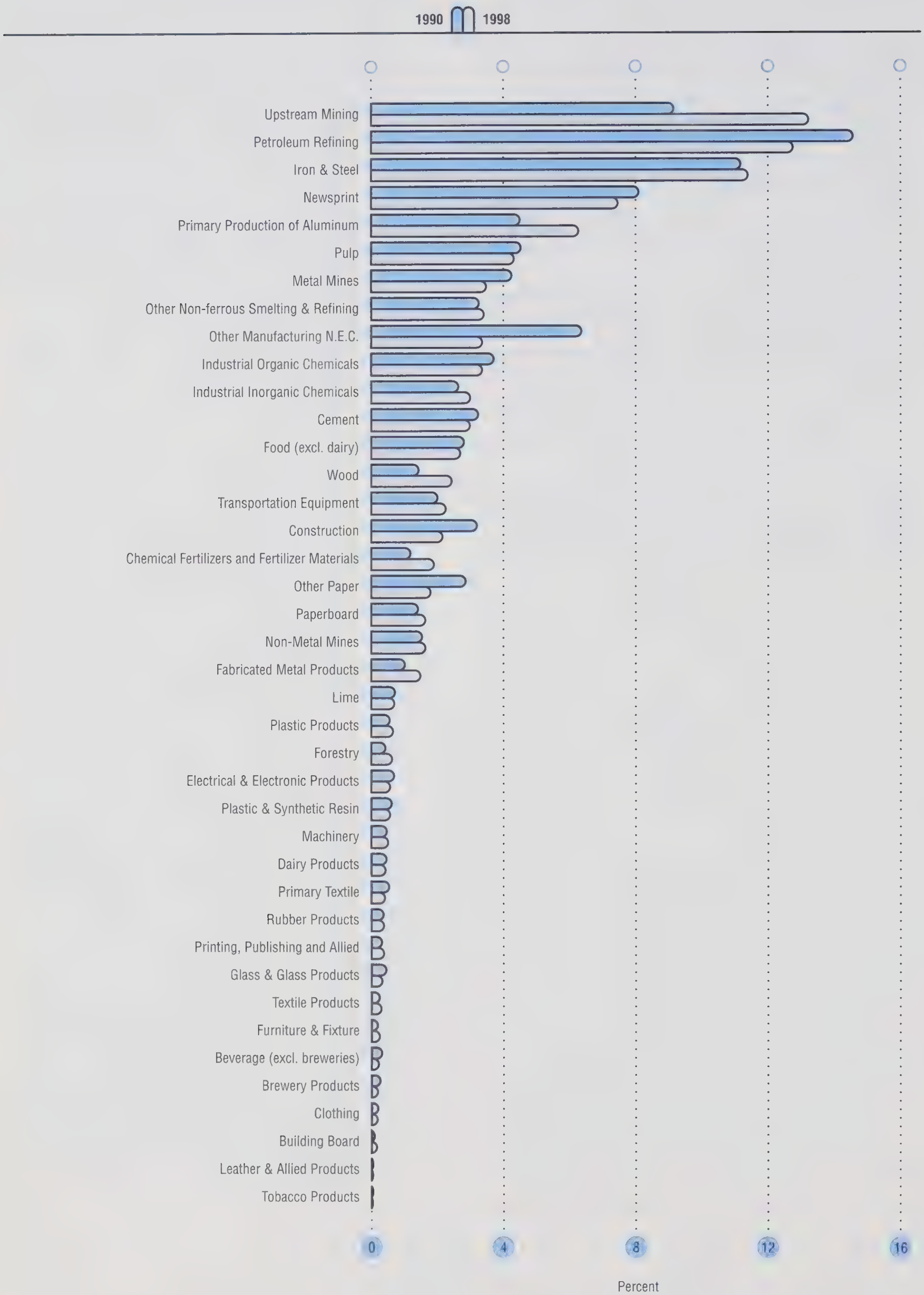
Figure 5.6 shows the distribution of GHG emissions by industry in 1990 and 1998. Five industries – upstream mining, petroleum refining, iron & steel, newsprint and primary production of aluminum – accounted for more than 50 percent of the sector's GHG emissions in 1998. These industries increased their share of emissions by 3.6 percentage points from 1990 to 1998, mainly as a result of increased energy use in upstream mining, wood and the primary production of aluminum. These three industries were the only industries to record an increase in emissions of more than 1 percentage point over the review period.

While increased reliance on fossil fuels for electricity generation put upward pressure on industrial GHG emissions, fuel shifting in other areas had the opposite effect. Between 1990 and 1998, as shown in Figure 5.7, there was a notable shift away from oil products, coal, coke and coke oven gas (decline of 3.1 percentage points) to the other, less GHG-intensive fuels (increase share by 1.6 percentage points) and electricity (increase share by 1.5 percentage points). If these shifts had not occurred, and energy had remained at its actual level, industrial GHG emissions would have increased by 12.9 percent and GHG intensity would have increased by 2.7 percent over the review period.

8 In this document, the universe used to calculate GHG emissions is different than the one used by CIPEC.

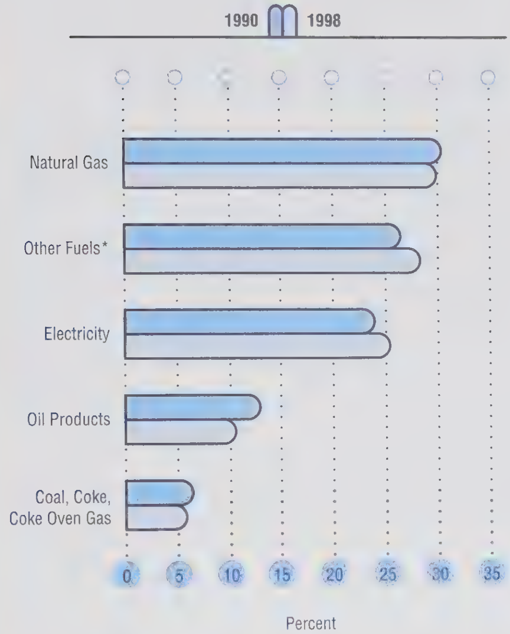
9 Emissions associated with electricity generation are calculated using a national average.

Figure 5.6: Industrial Greenhouse Gas Emissions by Industry, 1990 and 1998 (percent)



... with emissions from electricity and end-use omitted the sector's GHG intensity would have declined by 7.0 percent.

Figure 5.7: Industrial Energy Fuel Shares, 1990 and 1998 (percent)



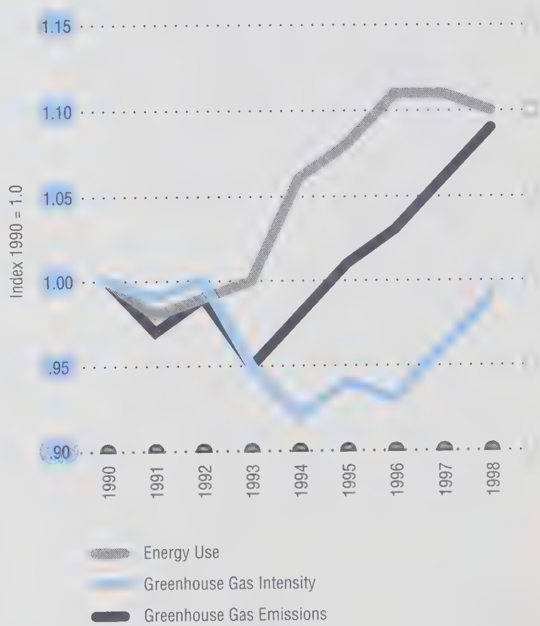
*Includes wood waste, pulping liquor, petroleum coke, still gas, steam and wood waste fuels.

The impact of fuel shifting is even more significant on an industry-by-industry basis. For example, the "other paper" industry increased its use of wood waste, spent pulping liquor and steam by 34 percentage points between 1990 and 1998, mostly at the expense of electricity and oil products. As a result, GHG emissions from this industry were 31 percent lower in 1998 than in 1990. If no fuel switching had occurred, emissions would have increased by 47 percent over the period. In fact, all industries in the pulp and paper sector of the economy increased their use of wood waste and pulping liquor, thus significantly improving the sector's GHG intensity.

Other industries also experienced notable fuel shifts between 1990 and 1998. The rubber products, leather and allied products, iron & steel and diary products industries increased their use of electricity and natural gas by more than 5 percentage points each mostly at the expense of oil products. Had these shifts not occurred, GHG emissions and GHG intensity in these industries would have been much higher in 1998 than was the case.

As Figure 5.8 demonstrates, the GHG intensity of the energy used by the industrial sector in 1998 was very close to the GHG intensity of 1990. As such, GHG emission levels increased approximately at the same rate as energy use.

Figure 5.8: Industrial Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, 1990–1998 (index 1990 = 1.0)



5.5 The Data Situation

The aggregate energy use data presented in this report are taken from Statistics Canada's *Quarterly Report on Energy Supply and Demand* (QRESD). The QRESD is used because it is Canada's official energy supply and demand balance and it is the basis of Canada's inventory of greenhouse gas emissions produced by Environment Canada.

Traditionally, QRESD data were estimated from a suite of Statistics Canada surveys of energy distributors and end-users. Up to 1993, most of the data were estimated from supply sources. As of 1994, the *Industrial Consumers of Energy* (ICE) survey, one of the sources of end-use data for the QRESD, has been greatly expanded. The 1995 survey included some 2000 respondents, up from a total of 230 respondents in 1993. As a result of expanding the ICE survey, data are now available for 24 industries at two digit level (SIC code), and for 31 sub-industries at three and four level (SIC code) rather than the previous 10. Environment Canada is now using these data to produce supplementary emissions estimates for these industries.

NRCan's understanding of how energy is used in Canadian industry has improved, as more information from the ICE survey becomes available. As a result of better data and discussions with Statistics Canada, we have made changes to the industrial energy use data. These changes better reflect demand and non-energy feedstock in the chemical industry between 1990 and 1998. A correction was also needed for industrial petroleum coke demand in 1996.

The expanded ICE survey was also used to derive a more disaggregated set of industrial energy use data for the 1990 to 1994 period. CIEEDAC, at Simon Fraser University, has developed a database to track the energy efficiency progress of various industry groups involved in CIPEC. Because CIPEC required disaggregated data going back to 1990 and the expanded ICE is available only since 1994, CIEEDAC has to use a combination of ICE survey and the *Annual Survey of Manufacturers* (ASM) data. This database allows us to develop physical measures of activity when appropriate and an economic measure of output for the entire 1990 to 1998 period.

In the last report (*Energy Efficiency Trends in Canada – An Update*), OEE expanded the database from 10 to 39 industries. In this report, a 40th industry has been added to the database – the dairy industry. The CIEEDAC database, containing energy use data by industry and fuel as well as physical unit of output for some industries, the OEE to expand its database. CIEEDAC energy use data are calibrated to the QRESD energy use data, in our database.

For some industries, a mix of physical units of production and GDP are used as an activity indicator.[10] The physical unit data are produced by Statistics Canada for the majority of these industries. Reported levels of production from industry associations were used for the remaining industries (e.g., production in hectolitres of beer) when data were not provided by Statistics Canada, or when association data appear to be more accurate.

In this report, a 40th industry has been added to the database – the dairy industry.

10 For a list of industries with physical unit of output as the activity indicator, see Table 5.2 on page 48.

Transportation Sector

Definition: The transportation sector in Canada includes activities related to passenger, freight and off-road transportation.

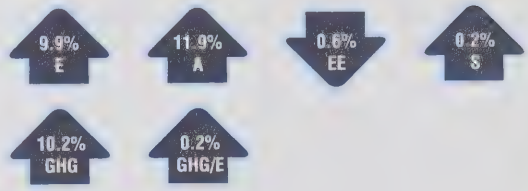
Non-commercial airline aviation is not included in the factorization analysis of the passenger transportation energy use.

Highlights

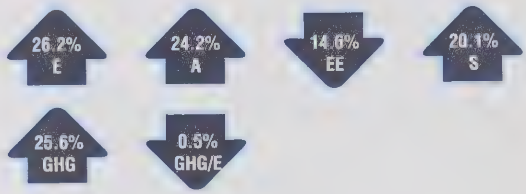
- From 1990 to 1998, energy use (E) in Canada's transportation sector increased by 16.2 percent, or 304 petajoules. This growth was the result of several factors:
  - Activity (A) in the sector increased. More people and more freight were moved over more kilometres. Activity in the freight transportation sub-sector (measured by tonne-kilometres) increased by 24.2 percent, while activity in the passenger transportation sub-sector (measured by passenger-kilometres) increased by 11.9 percent. Had only activity changed over the period, energy use would have increased by 159 petajoules for freight transportation and by 134 petajoules for passenger transportation.
  - Changes in structure (S) (shifts of activity between transportation modes) also resulted in increased energy use. Structural changes in passenger transportation had a minor impact on energy use (2 petajoules). However, the freight transportation sub-sector experienced a significant increase in trucking activity, at the expense of marine transportation, which affected the freight transportation activity mode mix and increased freight transportation total energy use by 132 petajoules.
  - In the freight transportation sub-sector, aggregate energy intensity increased by 1.6 percent, while its energy efficiency (EE) improved by 14.6 percent. In the passenger sub-sector, both aggregate energy intensity and energy efficiency remained close to their 1990 levels. Had only energy efficiency changed over the period, energy use would have decreased by 7 petajoules for passenger transportation and by 96 petajoules for freight transportation.
- Greenhouse gas (GHG) emissions from the transportation sector increased by 16.2 percent from 1990 to 1998, consistent with the overall growth in energy use.

The Energy/Emissions Barometer – Transportation Sector

Passenger[1]



Freight



6.1 Overview – Energy Use and Greenhouse Gas Emissions

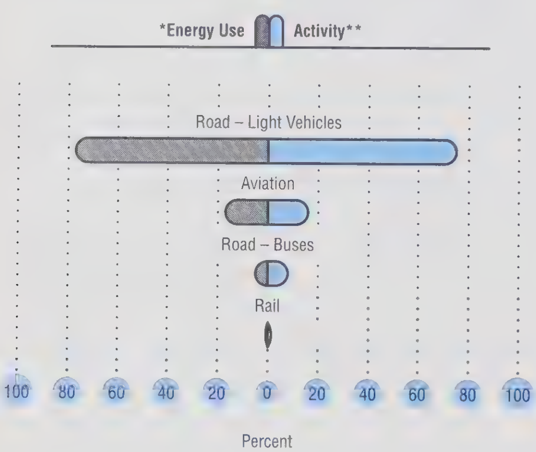
In 1998, energy use by the transportation sector totalled 2182 petajoules, or about 28.5 percent of secondary energy demand in Canada. Greenhouse gas emissions from transportation energy use were 157 megatonnes of CO_2 equivalent, or about 34.8 percent of total greenhouse gas emissions from secondary energy use.

Passenger transportation accounted for 58.9 percent (1285 petajoules) of the sector's energy use in 1998, followed by freight transportation at 37.9 percent (828 petajoules) and off-road transportation at 3.2 percent (69 petajoules). Due to its small portion of overall energy use and data limitations with regard to activity, off-road transportation is not included in the OEE's factorization analysis.

1 For the passenger transportation sub-sector, non-commercial airline aviation is included in the changes in energy use (E), greenhouse gas emissions (GHG) and greenhouse gas intensity (GHG/E). However, it is excluded from the factorization analysis, i.e., activity (A), energy efficiency (EE) and structure (S).

The passenger transportation sub-sector comprises four modes of transportation: light vehicles,[2] buses, aviation and rail. As illustrated in Figure 6.1, light vehicles accounted for 77.2 percent of the sub-sector's energy use in 1998 and 74.9 percent of activity, measured by passenger-kilometres.[3] When combined with buses, these modes of road transportation accounted for 82.6 percent of the energy used for passenger transportation and 83.3 percent of the activity. Aviation accounted for 17.2 percent of energy use and 16.4 percent of activity in 1998, while rail accounted for a much smaller proportion of energy use and activity in 1998.

Figure 6.1: Distribution of Passenger Transportation Energy Use and Activity by Mode, 1998 (percent)

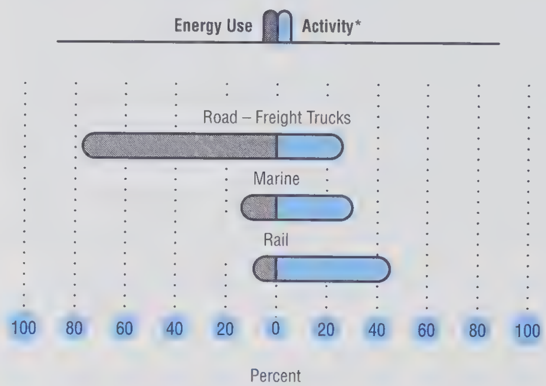


* Includes non-commercial airline aviation

** Measured in passenger-kilometres, excludes non-commercial airline aviation

The freight transportation sub-sector encompasses the movement of goods by freight truck, rail and marine modes of transportation.[4] Figure 6.2 shows that trucking accounted for the largest share of energy use (76.6 percent) in this sub-sector, followed by marine (14.3 percent) and rail (9.1 percent).[5] However, the distribution of activity, defined by tonne-kilometres, tells a different story. Freight trucks accounted for only 25.9 percent of total freight activity in 1998, while rail accounted for 44.5 percent and marine for 29.6 percent. This variation reflects the competitive advantages of carrying heavy loads on long distances by rail.

Figure 6.2: Distribution of Freight Transportation Energy Use and Activity by Mode, 1998 (percent)



*Measured in tonne-kilometres

Greenhouse gas emissions from the transportation sector increased by 16.2 percent from 1990 to 1998, primarily as a result of a 26.2-percent increase in freight transportation energy use. The greenhouse gas intensity of energy used decreased by less than 0.1 percent. Passenger and freight transportation accounted for 58.4 percent and 38.5 percent of total transportation emissions respectively, while off-road accounted for 3.1 percent. The road transportation modes, (i.e., light vehicles, freight trucks and buses) accounted for more than 77.1 percent of total transportation greenhouse gas emissions in 1998.

2 Light vehicles are defined as passenger cars, light trucks with a gross vehicle weight up to 3855 kilograms (8500 lbs) and motorcycles.

3 Passenger-kilometre data do not include non-commercial airline travel, as these activity data are not available. Moreover, while passenger-kilometre data exist for rail and air travel, the data for light vehicles and buses are estimated based on other factors. Where such estimates are used, efforts are made to substantiate trends through surveys. Although air-cargo activity data exist, all energy is kept within the passenger segment as most of the activity consists of air passenger travel.

4 All marine activity is allocated to the freight transportation sub-sector, since no data exist to allow a reliable division between freight and passenger transportation.

5 Activity data for the freight sub-sector cover all rail and all marine transportation, but only a portion of trucking activity. The data are limited to large commercial intercity trucking activities (with an annual revenue of $1 million), as reported by Statistics Canada, including the portion of international freight activity (import and export) that takes place inside Canada. Light- and medium-duty trucking activity (mainly service trucking) have been assigned a fixed weight-to-kilometre ratio as a proxy for activity. Marine freight data cover the domestic portion of marine transportation, as reported by Transport Canada.

6.2 Trends in Energy Use

Between 1990 and 1998, energy use in the transportation sector increased by 304 petajoules, or 16.2 percent, to 2182 petajoules. The largest increase was recorded in the freight transportation sub-sector, where energy use grew by 172 petajoules, or 26.2 percent. Energy use for passenger transportation, on the other hand, increased by 116 petajoules (9.9 percent). In the off-road sub-sector, energy use increased by 16 petajoules (30.7 percent).

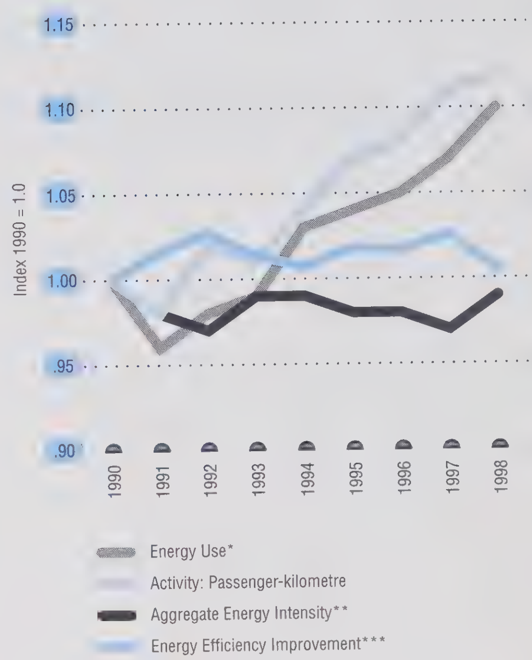
The remainder of this chapter focuses on factors that influenced changes in transportation energy use and greenhouse gas emissions from 1990 to 1998. The energy use data for passenger transportation and freight transportation are presented in separate sections. Finally, information is also provided on the data situation in the transportation sector.

6.3 Trends in Passenger Transportation Energy Use

Figure 6.3 illustrates the trends in passenger transportation energy use, aggregate energy intensity, activity and energy efficiency from 1990 to 1998.

As noted earlier, energy use for passenger transportation increased by almost 10 percent between 1990 and 1998. During the same period, activity increased by 11.9 percent. As a result, aggregate energy intensity – the ratio of energy used per kilometre travelled – in 1998 was very close to its 1990 levels, despite several years of improved performance. Aggregate energy intensity is affected by a wide range of factors, including fuel switching, technological improvements, shifts between different modes of transportation and behavioural changes. With an improvement of less than 1 percent, the energy efficiency of the passenger sub-sector in 1998 was also close to its 1990 level.

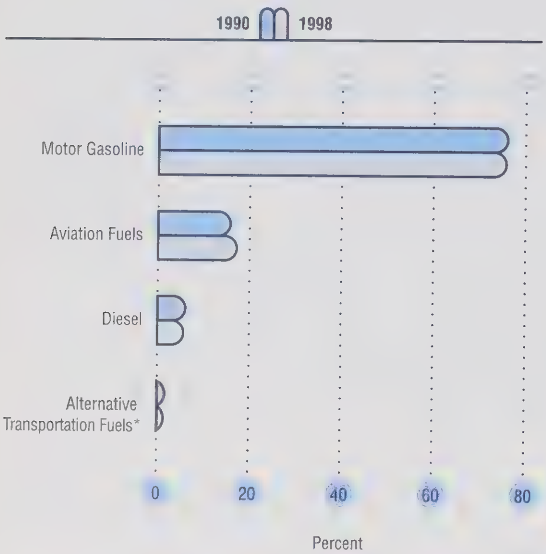
Figure 6.3: Passenger Transportation Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 (index 1990 = 1.0)



* Includes non-commercial airline aviation
** Excludes non-commercial airline aviation
*** This report presents an index of energy efficiency improvements while previous reports presented an index of the effects of energy efficiency on energy use.

Figure 6.4 provides a breakdown of fuel use in the passenger transportation sub-sector. Gasoline accounted for 75.8 percent of total energy use in this sub-sector in 1998, a decline of about one third of 1 percentage point from 1990. Almost 98 percent of the fuel used by light vehicles was in the form of gasoline, with the balance made up of diesel fuel and alternative transportation fuels. Aviation fuels accounted for 17.2 percent of total passenger transportation energy use in 1998.

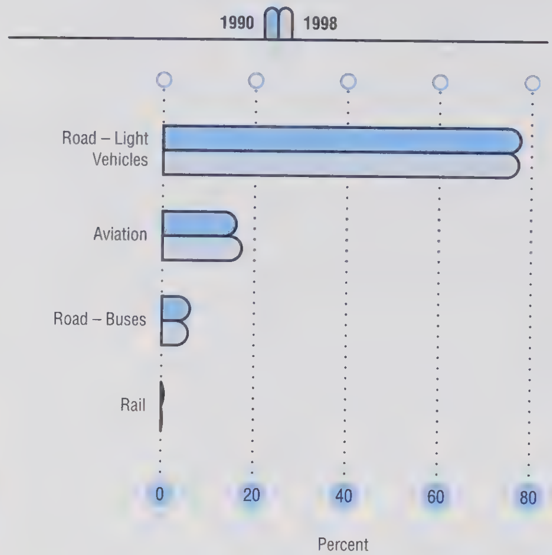
Figure 6.4: Passenger Transportation Fuel Shares, 1990 and 1998 (percent)



*Includes propane, natural gas and electricity

Minor changes were noted in the distribution of energy use among different transportation modes in 1990 and 1998. As illustrated in Figure 6.5, aviation's share of passenger transportation energy use increased slightly – from 16 percent in 1990 to 17.2 percent in 1998 – while all other modes experienced modest declines. Light vehicles lost some ground but still accounted for the largest share of passenger transportation energy use, at 77.2 percent in 1998. The rail mode's share declined to less than 0.2 percent in 1998.

Figure 6.5: Passenger Transportation Energy Mode Shares, 1990 and 1998 (percent)



6.3.1 Factors Contributing to Changes in Energy Use – Passenger Transportation

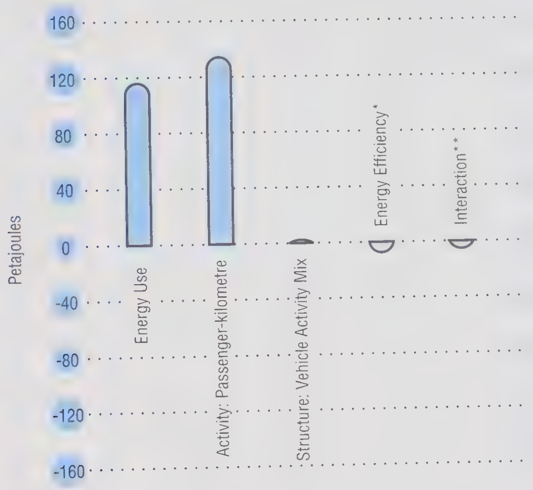
For the purposes of this report, changes in passenger transportation energy use over the review period have been attributed to three broad factors: changes in activity, changes in structure (shifts of activity between transportation modes) and changes in energy efficiency. The OEE's factorization analysis reveals that the growth in energy use between 1990 and 1998 was mainly due to growth in activity, while changes in structure had a minor impact (see Figure 6.6). These upward pressures on energy use were partly offset by a minor improvement in energy efficiency.

The Canadian preference for light trucks is the main factor responsible for the increased energy intensity.

Specifically, the analysis revealed that:

- had only activity changed over the 1990 to 1998 period, passenger transportation energy use would have increased by 134 petajoules;
- had only structure changed over the period, energy use would have increased by 2 petajoules;
- had only energy efficiency changed over the period, energy use for passenger transportation would have decreased by 7 petajoules; and
- aggregate energy intensity in the passenger transportation sub-sector in 1998 was at almost the same level as in 1990, despite several years of lower aggregate energy intensity.

Figure 6.6: Factors Influencing Growth in Passenger Transportation Energy Use, 1990–1998 (petajoules)



* Represents the effect of energy efficiency improvements on energy consumption.
** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.
Note: The factorization excluded non-airline aviation (-8.8 PJ).

These factors are discussed in further detail in the next four sections of this chapter, which consider the four modes of passenger transportation. Extra attention is devoted to light vehicles, since they account for more than three quarters of the sub-sector's energy use in 1998.

6.3.2 Light Vehicles

The definition of light vehicles used in this report encompasses cars of all sizes and light-duty trucks, including minivans and sport utility vehicles. In 1998, passenger cars accounted for 63.7 percent of the energy used by light vehicles, compared to 77.3 percent in 1990. Over the same period, the share of energy used by light trucks increased from 22.5 percent to 36.1 percent. Motorcycles used the remaining 0.2 percent of passenger transportation energy in both 1990 and 1998.

Consistent with their declining share of energy use, passenger cars accounted for a smaller share of passenger transportation activity in 1998 compared to 1990, recording declines of 4.3 percentage points for small car share and 5.3 percentage points for large car share to the total passenger-kilometres travelled by light vehicles. Nevertheless, cars still accounted for 73.9 percent of the total passenger-kilometres travelled by light vehicles in 1998.

Figure 6.7 shows the key factors that influenced energy use by light vehicles between 1990 and 1998. Energy use by passenger light vehicles increased by 9.3 percent (85 petajoules) between 1990 and 1998, while during the same period, activity increased by 8.3 percent. This represents a significant structural change since it is the first time since 1990 that energy use grew at a faster rate than activity. As a result, aggregate energy intensity increased over the review period, despite several years of improved performance. Canadian preferences for light trucks is the main factor responsible for the increased energy intensity. Passenger light truck energy use increased by 75.3 percent over the review. In 1998, 25.9 percent of passenger light vehicles in Canada were light trucks, compared to 16.1 percent in 1990. This structural change increased the energy use by 36 petajoules.

Reductions in light truck energy efficiency also increased energy use by 4 petajoules from 1990 to 1998. This increased energy use was offset by a significant improvement in large car energy efficiency. Had only energy efficiency changed over the period, energy use for light vehicles would have decreased by 35 petajoules.

Figure 6.7: Factors Influencing Growth in Light Vehicle Passenger Transportation Energy Use, 1990–1998 (petajoules)

* Represents the effect of energy efficiency improvements on energy consumption.

** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

Improvements in passenger car fuel efficiency usually include technological improvements to the body and drivetrain, as well as engine upgrades. Improvements to the body and drivetrain include transmission changes (e.g., increased number of gears, electronic overdrive), reduced weight, reduced drag (reduced wind resistance), as well as better performing tires that reduce tire resistance to road pavement (e.g., low-profile performance tire, synthetic rubber composition), lubricants (e.g., synthetic lubricant that reduces drivetrain friction) and accessories (e.g., electric cooling fans to replace belt-driven fans). Engine upgrades can improve fuel efficiency and performance through electronic controls, reduced internal friction, and better valve controls.

Table 6.1: Typical New Passenger Car Characteristics for 1970, 1990 and 1998

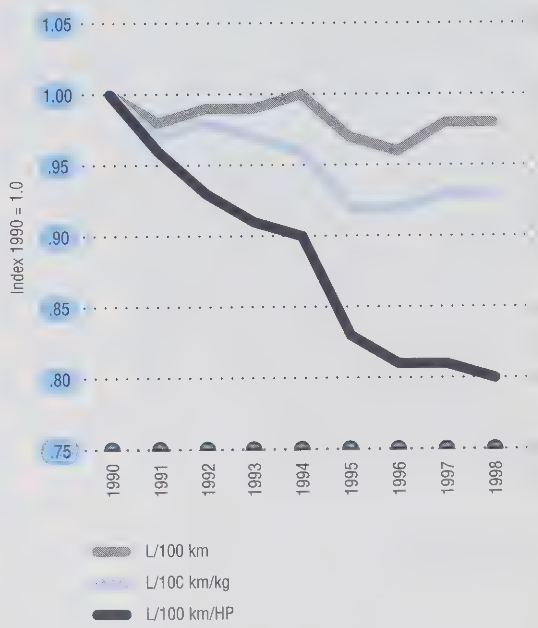
Feature	1970	1990	1998
Transmission	Typically Automatic	Manual (25%) Automatic (75%)	Manual (22%) Automatic (78%)
Number of gears	3	3–4	4
Control	Mechanical	Mechanical	Electronic
Overdrive	None	Electronic (64%) Manual transmission (36%)	Electronic
Drive	Rear wheel	Front wheel (91.6%) Rear wheel (7.7%) 4x4 (0.7%)	Front wheel (93.8%) Rear wheel (4.4%) 4x4 (1.7%)
Weight	More than 4000 lbs.	About 2720 lbs.	About 2850 lbs.
Drag	More than 40	Below 40	Below 30
Tires	Belted	Radial	Radial
Engine	6–8 cylinders	4 cylinders (62%) 6 cylinders (31%)	4 cylinders (66%) 6 cylinders (29%)
Fuel control	Carburetor	40% fuel injection; mostly throttle body	Multi-point fuel injection
Valves per cylinder	2 valves	2 valves (72%) 4 valves (23%)	2 valves (30%) 4 valves (61%)
Horsepower	Approx. 135	Approx. 118	Approx. 145
Lab-tested fuel economy	13.3 L/100 km	8.2 L/100 km	8.0 L/100 km

The typical 1970 passenger car weighed more than 4000 pounds and had rear-wheel drive, poor aerodynamics, an eight-cylinder, carburetor engine and a three-speed automatic transmission. However, passenger cars gradually changed (see Table 6.1). In 1990, new passenger cars typically weighed about 2700 pounds, and more than 90 percent of these vehicles had front-wheel drive. Four- and six-cylinder engines with throttle-body fuel injection and overdrive transmissions were also more common. These changes led to a 38.3-percent improvement in fuel efficiency between 1970 and 1990.

In 1998, new passenger cars commonly had better fuel economy than in 1990. Technological improvements, such as electronic engine control, reduced drag and multi-point fuel injection engines, were more than offset by the trend toward heavier and more powerful vehicles in the 1990s. To detect the fuel efficiency improvements resulting from technological improvements, alternative ways to measure energy efficiency are required. Two alternative measures are illustrated in Figure 6.8 where the conventional measure of fuel economy (L/100 km) is standardized for (divide by) weight (and, thus, size) and standardized for power.

These alternative indicators of fuel consumption have shown more rapid improvement than the conventional measure of L/100 km. Whereas the fuel consumption (L/100 km) of new passenger cars decreased by only 1.8 percent from 1990 to 1998, the fuel consumption measured in terms of L/100 km/kg over the same period decreased by 7.4 percent; and measured in terms of L/100 km/hp, it decreased by 19.9 percent. However, these improvements in fuel efficiency were more than offset by the negative impact of consumer preferences for greater vehicle weight and power in the 1990's.

Figure 6.8: New Passenger Car Fuel Economy, Normalized for Weight and Power, 1990–1998 (index 1990 = 1.0)



6.3.3 Buses

The bus mode includes school buses, as well as urban and intercity buses.[6]

Urban buses are the predominant energy user in this mode, accounting for 69.8 percent (49 petajoules) of total bus energy use in 1998, compared to 65.4 percent in 1990. The share of energy used by intercity buses declined by 4.8 percentage points during the review period, and stood at 10.6 percent (7 petajoules) of the total in 1998. School buses accounted for 19.7 percent (14 petajoules) of total energy use by buses in 1998.

6 In the Statistics Canada catalogue *Passenger Bus and Urban Transit Statistics* (Cat. No. 53-215-XIB), the data reported for school buses increased dramatically while the data for intercity buses declined by a similar amount. These changes were largely caused by mergers and acquisitions in the bus industry, which resulted in some information on intercity buses being reported in the school bus category by Statistics Canada. Adjustments were made to school and intercity bus data to minimize this inconsistency.

Urban buses also have the greatest share of activity in this transportation mode. They accounted for 47.9 percent in 1998 compared to 46.7 percent in 1997. School buses accounted for 32 percent of total bus activity in 1998, an increase of 3.7 percentage points from 1990. The bus passenger transportation sub-sector experienced a gain in energy efficiency over the review period which offsets increased bus activity in urban areas. Gains in energy efficiency decreased energy use by 2.5 percent while increased activity raised energy use by 2.6 percent. Bus passenger transportation also experienced some minor structural changes with an increase in the activity share of urban buses and a reduction in the activity share of intercity buses. This structural change increased energy use by 1.2 percent (1 petajoule).

6.3.4 Rail

The amount of energy used to move passengers by rail dropped by 56.9 percent between 1990 and 1998. This was due to reductions in both activity (resulting in a decline in energy use of 1 petajoule) and energy efficiency (resulting in a decline of 2 petajoules).

6.3.5 Aviation

Aviation travel accounted for 17.2 percent (221 petajoules) of passenger transportation energy use in 1998 compared to 16.0 percent in 1990. In the passenger transportation segment, aviation was the only transportation mode to increase its share of energy use between 1990 and 1998.

In terms of activity, the aviation mode was responsible for 16.4 percent of total passenger-kilometres in 1998. Between 1990 and 1998, the aviation mode increased its share of total passenger-kilometres by 3.4 percentage points. Had only activity changed in the period, aviation energy use for passenger transportation would have increased by 61 petajoules. However, energy efficiency improvements in this mode helped offset the increased activity. Had only energy efficiency changed, energy use would have declined by 14 petajoules.

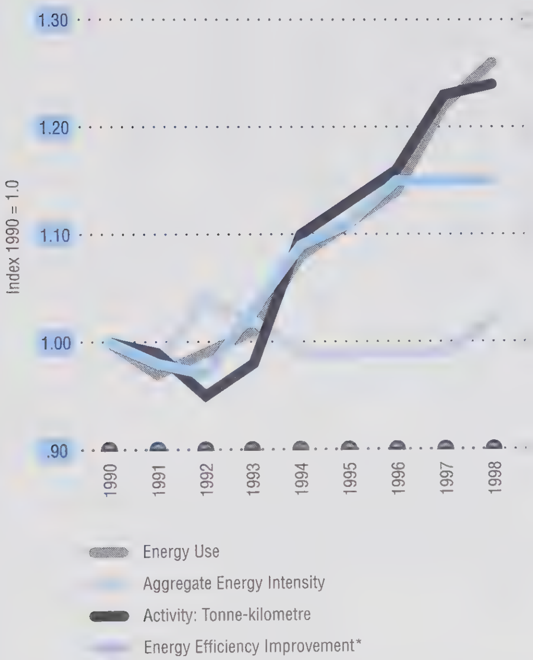
6.4 Trends in Freight Transportation Energy Use

Figure 6.9 shows the trends in freight transportation energy use, aggregate energy intensity, activity and energy efficiency from 1990 to 1998.

As noted earlier, energy use for freight transportation increased by 26.2 percent between 1990 and 1998. During the same period, freight activity increased by 24.2 percent and energy efficiency improved by 14.6 percent. This is the first time since 1993 that energy use for freight transportation increased at a faster rate than freight activity. As a result, the aggregate energy intensity was higher for the freight transportation sub-sector in 1998 than in 1990.

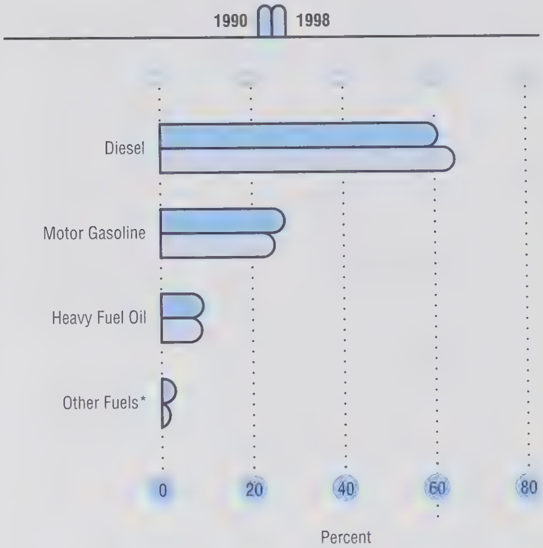
Aviation was the only passenger transportation mode to increase its share of energy use between 1990 and 1998.

Figure 6.9: Freight Transportation Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 (index 1990 = 1.0)



*This report presents an index of energy efficiency improvements while previous reports presented an index of the effects of energy efficiency on energy use.

Figure 6.10: Freight Transportation Fuel Shares, 1990 and 1998 (percent)



*Propane, natural gas, coal, kerosene and light fuel oil

Figure 6.10 provides a breakdown of fuel use in the freight transportation sub-sector. Diesel fuel accounted for 64.4 percent of total energy use in this sub-sector in 1998, an increase of 3.7 percentage points over 1990. At the same time, gasoline's share of total freight energy use decreased from 27.1 percent to 24.9 percent. Heavy fuel oil's share declined slightly to 8.9 percent of the total, while the share of "other fuel" declined to 1.8 percent.

The increased use of diesel fuel was primarily a result of growth in the number of large trucks, all of which are diesel fuelled.[7] Large trucks accounted for 41 percent of total freight energy use in 1998, and 20.4 percent of freight activity. Some of the increase in diesel usage can also be attributed to fuel switching, particularly among medium-duty trucks, where the use of diesel fuel increased by 67.2 percent at the expense of gasoline. For the first time since 1990, diesel accounted for a higher share (51.3 percent) than gasoline of the energy used by medium-duty trucks in 1998. Conversely, 89.5 percent of light trucks use gasoline.

7 Large trucks have a gross vehicle weight (GVW) of more than 14 970 kilograms. Medium-duty trucks have a GVW ranging from 3856 to 14970 kilograms, and light trucks are those with a GVW up to 3855 kilograms.

6.4.1 Factors Contributing to Changes in Energy Use – Freight Transportation

For the purposes of this report, changes in freight transportation energy use over the review period have been attributed to three broad factors: changes in activity, changes in structure and changes in energy efficiency. The OEE's factorization analysis (illustrated in Figure 6.11) reveals that the growth in freight energy use between 1990 and 1998 was the result of significant growth in activity and major changes in structure (notably a shift of activity toward trucks mainly at the expense of marine transportation). These upward pressures were offset somewhat by improvements in energy efficiency.

Specifically, the analysis revealed that over the review period 1990 to 1998

- had only activity changed, freight transportation energy use would have increased by 159 petajoules;
- had only structure changed, freight transportation energy use would have increased by 132 petajoules; and
- had only energy efficiency improved, freight transportation energy use would have decreased by 96 petajoules.

These factors are discussed in further detail in the following sections of this chapter, which consider the three modes of freight transportation – freight trucks, rail and marine.

Figure 6.11: Factors Influencing Growth in Freight Transportation Energy Use, 1990–1998 (petajoules)

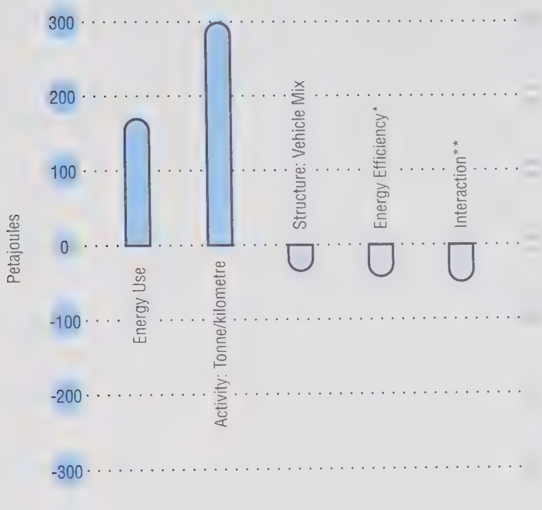
* Represents the effect of energy efficiency improvements on energy consumption.
** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

6.4.2 Freight Trucks

Figure 6.12 shows the key factors that influenced the 36.4-percent increase in freight truck transportation energy use between 1990 and 1998 (169 petajoules). The most important factor was a 64.1-percent increase in activity. This was partly offset by improved energy efficiency.

Significant changes have occurred in Canada's trucking industry over the past 10 years. The deregulation process launched in 1987 culminated in 1993, with amendments to the *National Vehicle Transportation Act* that have made it easier for new carriers to enter the industry. As well, the signing of the Canada–U.S. Free Trade Agreement in 1989 and the broader North American Free Trade Agreement in 1992 have altered the flow of trade between Canada and the United States. About two thirds of the dollar value of this trade moves by freight truck.

Figure 6.12: Factors Influencing Growth in Road Freight Transportation Energy Use, 1990–1998 (petajoules)



* Represents the effect of energy efficiency improvements on energy consumption.
** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

Deregulation and free trade have resulted in greater competition and increased activity in the Canadian trucking industry. Between 1990 and 1998, when Canada's economy was growing at an annual rate of about 2 percent, the trucking industry's output increased at an average annual rate of 5 percent, compared to only 1 percent per year for the rail transportation industry and a decline of 1 percent per year for the marine industry. Growth in international trade – attributed mainly to increased trade in consumer goods, equipment and machinery and automotive goods – led to corresponding increases in freight activity. The relative weakness of the Canadian dollar (compared to the U.S. dollar) also stimulated growth in Canadian exports, and thus in the demand for freight transportation by truck.

Changes in the composition of the truck fleet also had a significant impact on energy use. The fleet of diesel trucks registered as commercial vehicles in Canada increased by 39 percent over the review period. Diesel trucks represented 25 percent of freight trucks in 1998, an increase of 3 percentage points over 1990. The road freight transportation also experienced some structural changes over the review period with a significant increase in large-truck activity at the expense of light and medium-duty trucks. Without this structural change, road freight energy use would have increased by 205 petajoules instead of 169 over the 1990 to 1998 period.

Many trucking companies have responded to changes in the freight industry by improving their efficiency, entering into strategic partnerships, merging their operations or making new acquisitions. Efficiency improvements have been achieved mainly by consolidating loads (filling a truck to its maximum capacity) and increasing back-haul movements (loads picked up by a truck that would otherwise be empty after it has delivered its original load). The industry has also focused on providing better services, such as just-in-time delivery at competitive prices. This has increased the efficiency – and the demand for – trucking services. Had only energy efficiency changed, energy use would have decreased by 9.3 percent (43 petajoules).

6.4.3 Rail

The rail industry also benefited from a more competitive marketplace in the past decade, again as a result of free trade and the removal of most economic regulations faced by the industry.

During this period, Canada's two largest railways rationalized their operations by scaling back activities, abandoning uneconomic lines and selling certain assets (some activities were subsequently taken up by new short-line railways operating parts of the old system). The two large railways also integrated their operations on a continental basis, establishing north-south links through acquisitions, partnerships and investments in infrastructure to eliminate bottlenecks. Also, during the review period, certain types of rail equipment were replaced with the goal of increasing economy and fuel efficiency. For example, the number of freight locomotives in the stock was reduced by 9.7 percent over this period.

Overall, these developments laid the groundwork for lower energy use, higher activity levels and more efficient rail networks. Improvement in energy efficiency reduced the rail energy use by 22 petajoules, while at the same time the rail industry increased its activity by 20.6 percent. As a result, rail energy used decreased 11 percent over the review period.

6.4.4 Marine

In 1998, about 376 million tonnes of domestic and international cargo were loaded and unloaded at Canadian ports. In 1998, Canadian port activity was at almost the same level as in 1997 while international bulk cargo exports declined significantly – after several years of growth – due to the Asian financial crisis. The decline in international cargo exports was offset by an 3.4-percent increase in domestic cargo handled at the port. Canadian port activity increased by 6.5 percent between 1990 and 1998 mainly due to the growth in international cargo exports from 1990 to 1997.

In terms of tonne-kilometres (i.e. the cargo tonnage that travelled a distance of one kilometre), the change in marine activity was relatively minor from 1990 to 1998, reflecting an increase in the cargo's distance travelled proportionnal to the change in cargo tonnage handled by Canadian ports. In 1998, 29.6 percent of Canada's total freight tonnage was moved by ship, compared to 34.6 percent in 1990.

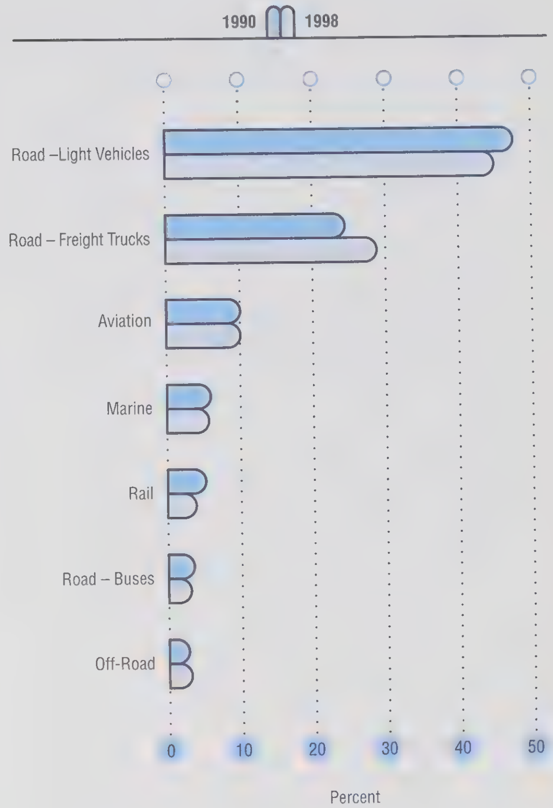
6.5 Trends in Greenhouse Gas Emissions

Greenhouse gas emissions from the transportation sector increased by 16.2 percent from 1990 to 1998, primary as a result of a 26.2-percent increase in freight transportation energy use. The greenhouse gas intensity of energy used increased by less than half of 1 percent to reach 72 tonnes per terajoule (see Figure 6.13). This is 40.3 percent higher than the industrial sector's greenhouse gas intensity of energy use, more than 33.8 percent higher than in the residential sector and 26.2 percent higher than the commercial sector. Energy used in the agricultural sector has about the same greenhouse gas intensity as in the transportation sector.

Figure 6.13: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Transportation Sector, 1990–1998 (percent)

Road transportation (i.e., light vehicles, freight trucks and buses) accounted for more than 77.1 percent of total transportation greenhouse gas emissions in 1998, approximately the same proportion as in 1990. However, the share of freight trucks to the sector's total greenhouse gas emissions increased significantly (4.3 percentage points) over the review period. Light passenger vehicles (-2.7 percentage points) and buses (-0.5 percentage points) decreased over the same period. Aviation is the second largest contributor to the transportation greenhouse gas emissions with 10.2 percent in 1998, while marine and rail together represented less than 10.0 percent (see Figure 6.14). While marine activity increased over the review period, its share of total transportation emissions declined by 0.3 percentage point.

Figure 6.14: Transportation Greenhouse Gas Emissions Shares by Mode, 1990 and 1998 (percent)



As shown in Figure 6.15, transportation greenhouse gas emissions and energy use have followed the same trends since 1990. Both decreased by 4 percent between 1990 and 1991 then constantly increased. Between 1991 and 1998, transportation emissions and energy use increased by 21 percent. The greenhouse gas intensity of energy remained almost constant over the review period, which is indicative of the historically strong relationship that exists between energy and greenhouse gas emissions growth in this sector.

Figure 6.15: Transportation Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity 1990–1998 (index 1990 = 1.0)

6.6 The Data Situation

The data used in this chapter come from various sources. For example, only partial information is available for measures of activity. Calibration procedures are used to complement this information. Since the previous complete edition of this report (*Energy Efficiency Trends in Canada 1990 to 1996*), efforts have been made to better represent the actual stock of passenger cars and freight trucks in operations in Canada and to improve the quality of the information related to bus energy demand.

The quantification and assessment of energy efficiency trends in the road transportation sector require the use of reliable and accurate information on the stock of vehicles in operation in Canada and each province. Such information is gathered annually in Canada through the provincial vehicle registration offices. Their registration procedures are not uniform, but each registrar collects detailed information on vehicles registered in the province.

The vehicle stock data used in this chapter has changed since the previous complete edition of this report. In the earlier edition, the vehicle stock data were based on Statistics Canada's publication, *Road Motor Vehicles, Registrations* (catalogue no. 53-219-XIB). In order to use a greater level of vehicle stock detail in the OEE's analysis of the Transportation Sector, data sources were changed to be vehicle-chassis based. These new data allow for analysis of the vehicle stock by weight class, fuel type and model year.

In *Road Motor Vehicles, Registrations*, in the table entitled "Road Motor Vehicles – Registrations, Licences and Permits," Statistics Canada publishes national and provincial information on the number of vehicle registrations for different classes of vehicles (mainly passenger cars, trucks, buses, motorcycles, moped and off-road vehicles). Historically, this information is collected through a two-page questionnaire sent to each provincial registrar and then compiled and published by Statistics Canada as reported by each province.[8]

8 Statistics Canada intends to revise the *Road Motor Vehicles, Registrations* catalogue using data collected from the provincial registrars for the *Canadian Vehicle Survey* which will facilitate inter-jurisdictional comparisons.

Other organizations compile more detailed information on the stock of vehicles in Canada, by province, such as those mentioned earlier (weight class, fuel type and model year). The collection methodology used by these organizations rely on the vehicle's chassis to classify the vehicles as a passenger car or a truck. In addition, a data cleaning procedure is used to include only registrations with a valid licence plate and to remove duplicate vehicle registrations that may have appeared due to vehicle owners moving within or between provinces.

Table 6.2 below shows the difference in the total stock of passenger cars and trucks by comparing Statistics Canada data with the OEE's Transportation Energy Demand Model (TEDM) data, which uses data compiled using the vehicle-chassis based methodology.[9]

Table 6.2: Passenger Car and Truck Stocks Registered in Canada in 1990, 1995 and 1998

1990	Statistics Canada	TEDM*	Change in %
Passenger Cars	12 023 285	11 100 368	-7.7%
Trucks	3 814 063	4 282 410	12.3%
Total	15 837 348	15 382 778	-2.9%
1995			
Passenger Cars	12 366 296	10 936 126	-11.6%
Trucks	4 027 590	5 372 344	33.4%
Total	16 393 886	16 308 470	-0.5%
1998			
Passenger Cars	12 999 597	10 757 621	-17.2%
Trucks	4 304 958	6 424 299	49.2%
Total	17 304 555	17 181 920	-0.7%

* Passenger car and truck stocks from the OEE's Transportation Energy Demand Model (TEDM) using DesRosiers and Polk Canada data sources.

Using the new detail of data sources, the definition of the vehicle stock was modified, since the previous complete edition of this report, to harmonize the size class of passenger light-duty vehicles with the vehicle class targeted under the Motor Vehicle Fuel Consumption Program (MVFCP).[10] Light-duty and medium-duty trucks are now defined as 0 to 3 855 kg (0 – 8 500 lb.) and 3 856 to 14 969 kg (8 501 – 33 000 lb.), respectively.

All these changes have had a notable impact on the energy use trends reported for the review period (1990–1998). The following describes some of the impacts:

- Had the modifications not been made, the road passenger transportation energy use would have increased by 12.2 percent between 1990 and 1998 instead of 8.8 percent and would have accounted for 52.0 percent of total transportation energy use in 1998 instead of 55.1 percent. The road freight transportation energy use would have increased by 31.2 percent between 1990 and 1998 instead of 36.4 percent and would have accounted for 24.4 percent of total transportation energy use in 1998 instead of 29.1 percent.
- In the passenger transportation sub-sector, the changes in modelling and data sources had a particularly notable impact on the passenger car and light truck energy use. Without these changes, passenger car energy demand would have increased by 52 petajoules between 1990 and 1998 instead of decreasing by 69 petajoules. The passenger light truck energy use would have increased by 83 petajoules instead of 154 petajoules.
- In the freight transportation sub-sector, the light and medium-duty truck energy uses would have increased by 9.3 percent and 10.2 percent respectively between 1990 and 1998 instead of 19.8 percent and 24.3 percent, had the modelling and data sources modifications not been made.

9 The OEE's Transportation Energy Demand Model uses data compiled by DesRosiers Automotive Consultants for light-duty vehicles (passenger cars and light trucks) and Polk Canada Marketing Services Inc. for freight trucks.

10 The Motor Vehicle Fuel Consumption Program sets voluntary fuel efficiency standards for new vehicles and encourages manufacturers to produce and sell more fuel-efficient cars and light trucks.

Agriculture Sector

Definition: The agriculture sector in Canada includes all types of farms, including livestock, field crop, grain and oilseed farms. The data in this chapter are related to energy used for farm production and include energy use by establishments engaged in agricultural activities and in providing services to agriculture. It does not include the personal energy use of farmers.

Highlights

- From 1990 to 1998, energy use (E) in Canada's agriculture sector increased by 12.8 percent, or 26 petajoules. This was primarily the result of:
  - a 8.1-percent increase in activity (measured by gross domestic product. Had only activity changed over the period, energy use would have been 4.2 percent lower in 1998 than actual consumption (i.e., 215 petajoules instead of 225 petajoules).
  - a 4.4-percent increase in aggregate energy intensity.
- Greenhouse gas (GHG) emissions from the agriculture sector increased by 15.9 percent from 1990 to 1998. Most of this growth was due to increased energy use, as well as a 2.7-percent increase in the greenhouse gas intensity of energy use.

The Energy/Emissions Barometer – Agriculture

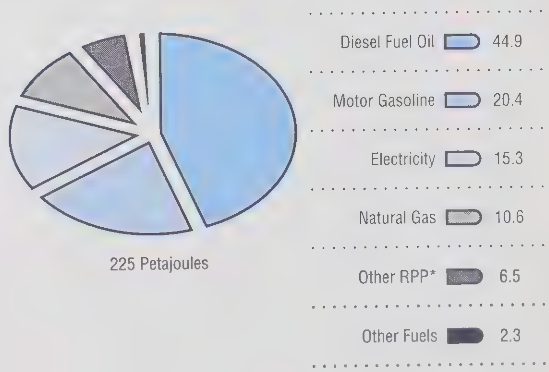
7.1 Overview – Energy Use and Greenhouse Gas Emissions

In 1998, energy use by the agriculture sector of the economy totalled 225 petajoules, or 2.9 percent of secondary energy demand in Canada. Greenhouse gas emissions from agricultural energy use were 16 megatonnes, or about 3.5 percent of total greenhouse gas emissions from secondary energy use. The sector's share of greenhouse gas emissions is greater than its share of energy use because of the greenhouse gas-intensive energy forms used in agriculture.

Since the last report, the definition of agricultural activity has been changed to better reflect the agricultural operations that contribute to the use of energy in the sector. Under the new definition, the gross domestic product (GDP) for the agricultural sector includes all agricultural and related service industries.

As illustrated in Figure 7.1, motive power is the dominant energy requirement in the agriculture sector, with gasoline and diesel fuel accounting for 65.4 percent of total energy use. Gasoline and diesel fuel also account for 91.0 percent of the refined petroleum products (RPPs) used in the sector. Gasoline use decreased by 18.1 percent over the review period, while diesel use increased by 41.1 percent. RPPs, natural gas and other fuels are used mainly for space heating (e.g., greenhouses and barns) and for drying crops. Electricity is used in multiple applications and increased by 10.9 percent between 1990 and 1998.

Figure 7.1: Distribution of Agricultural Energy Use by Fuel Type, 1998 (percent)



7.2 Trends in Energy Use

Figure 7.2 illustrates the trends in agriculture sector energy use, aggregate energy intensity and activity from 1990 to 1998.

Figure 7.2: Agricultural Energy Use, Aggregate Energy Intensity and Activity, 1990–1998 (index 1990 = 1.0)

Energy use in Canada's agriculture sector increased by 12.8 percent during the review period, growing from 199 petajoules in 1990 to 225 petajoules in 1998. Activity in the sector increased by 8.1 percent over the period. Although a variety of sources are available to provide detailed information on farm production, total GDP is used to measure the activity in the sector. The use of an aggregate definition of agricultural activity is needed to ensure consistency with the sector's energy use definition. Only aggregate information is available on the agricultural energy use. This implies that the analysis of the sector has been done at an aggregate level.

Although GDP is a good aggregate measure, it can be inordinately affected by cyclical changes in the broader economy. This variability is reflected in the report's estimate of energy intensity.

7.2.1 Factors Contributing to Changes in Energy Use

For the purposes of this report, changes in agricultural energy use over the review period have been attributed to two broad factors: changes in activity and changes in aggregate energy intensity. Changes in structure (the mix of agricultural activity) also influence energy use and may have been significant during the review period. However, due to a lack of available data, structure has not been included in the OEE's factorization analysis for the agriculture sector.

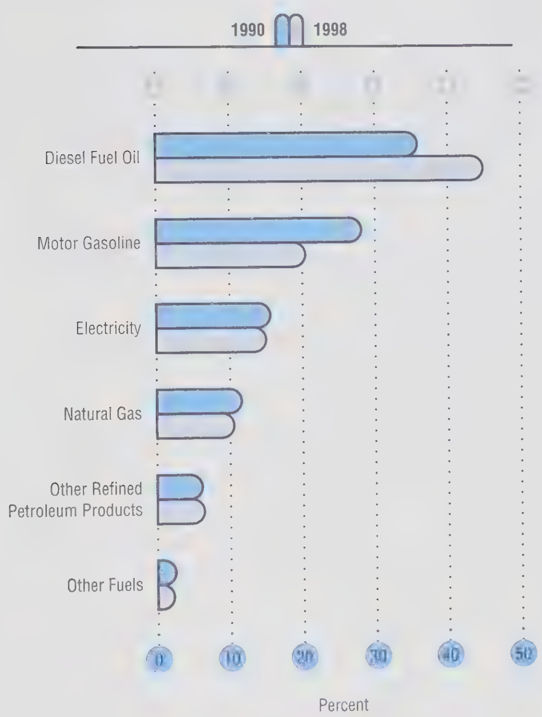
7.2.2 The Activity Effect

The results of the analysis reveal growth in agricultural activity from 1990 to 1998 and an increase in aggregate energy intensity. Had only activity changed over the review period, energy use would have been 215 petajoules in 1998, rather than 225 petajoules. Aggregate energy intensity rose by 4.4 percent between 1990 and 1998.

Most of the growth in energy consumption during the review period is accounted for by increased use of diesel fuel. Figure 7.3 shows that gasoline's share of energy use declined by about 7.7 percentage points between 1990 and 1998, while diesel fuel's share increased by about 9.0 percentage points. Two factors explain this trend:

- increased sales of diesel vehicles. Farmers are showing a preference for diesel-powered trucks and other farm vehicles because diesel engines are more powerful, have a longer life span, provide greater torque and are much more fuel efficient than comparable gasoline engines.
- differences in the tax treatment of diesel fuel and gasoline. "Purple" diesel fuel – fuel used for agricultural purposes only – is sold to farmers tax free. Farmers pay the full price for gasoline (including tax), but can apply for a tax refund.

Figure 7.3: Agricultural Energy Fuel Shares, 1990 and 1998 (percent)



7.2.3 The Aggregate Energy Intensity Effect

Aggregate energy intensity in the agriculture sector is influenced by factors such as the mix of agricultural production, weather conditions, the technology used and agricultural practices.

Changes in agricultural practices have a particularly notable impact on energy use. In recent years, farmers have been moving away from the conventional tillage practices of the past toward a technique known as zero tillage. Reduced tillage means reduced vehicle use, which has slowed the growth in demand for motive fuels. This trend was offset slightly during the review period by an increase in the amount of land used for cropping, as opposed to being left fallow for the summer.

Weather has a significant influence on energy consumption in agriculture. In wet years, the fuel consumption of farm vehicles increases because of poor off-road conditions and large quantities of grain that need to be dried, a process that uses propane or natural gas. In dry years, there is an increase in energy use for irrigation, but this increase is not considerable compared to the increase in energy use in wet years. In cold years, an increase in energy use results from the increased heating requirements of green-houses and barns, etc.

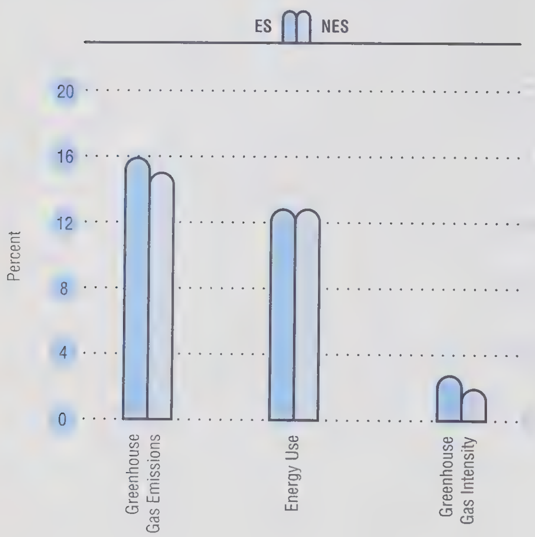
The temperature in Canada was about 14.0 percent warmer than normal in 1990.[1] In 1998, the temperature was nearly 40 percent warmer than normal following two years of relatively normal temperatures recorded in 1996 and 1997.

1 The percentage is measured in cooling degree days: however, the measure of heating degree days also indicated that 1998 was warmer than 1990 and 1990 was warmer than usual for Canada.

7.3 Trends in Greenhouse Gas Emissions

Figure 7.4 shows the growth in greenhouse gas emissions, energy use and greenhouse gas intensity in the agriculture sector from 1990 to 1998.

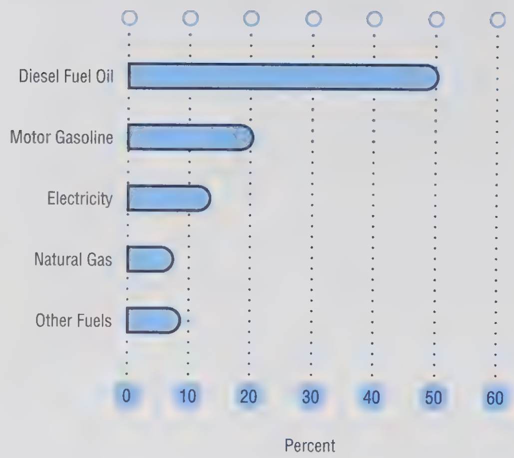
Figure 7.4: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Agricultural Sector, 1990–1998 (percent)



ES: Electricity End-Use Emissions Scenario
NES: No Electricity End-Use Emissions Scenario

Greenhouse gas emissions from agricultural energy use increased by 15.9 percent over the period, primarily as a result of the strong growth in activity.[2] The increased use of diesel fuel also contributed significantly to the growth in emissions. The share of emissions from diesel fuel in the agricultural sector increased from 41.4 percent in 1990 to 50.4 percent in 1998. Emissions from motor gasoline, the next largest source of emissions, accounted for about 20.3 percent of total emissions in the sector in 1998.

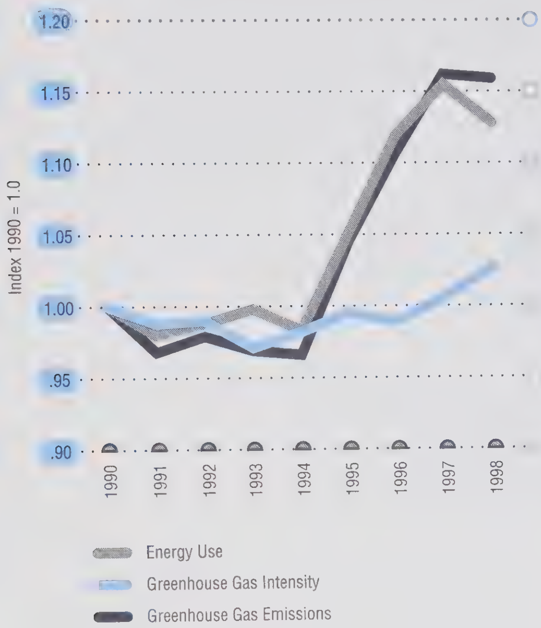
Figure 7.5: Agriculture Greenhouse Gas Emissions by Fuel Type, 1998 (percent)



The discrepancy between growth in emissions (at 15.9 percent) and growth in energy use (at 12.8 percent) is mainly a result of a 2.7-percent increase in the greenhouse gas intensity of energy use. The latter is due to an increase in the greenhouse gas intensity of power generation. Various fuels including natural gas, motor gasoline and diesel fuel were used in the agriculture sector to generate power. The mix of fuels used in 1998 to generate power was more greenhouse gas intensive than the mix in 1990.

2 The definition of agricultural energy demand and related greenhouse gas emissions used in this report differs from the one used by Environment Canada in the document, *Canada's Greenhouse Gas Inventory, 1997: Emissions and Removals with Trends.* See Appendix E of this report for a detailed explanation.

Figure 7.6: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Agriculture Sector, 1990–1998 (Index 1990 = 1.0)



7.4 The Data Situation

The energy use data used in this chapter come from Statistics Canada's *Quarterly Report on Energy Supply-Demand in Canada.* Informetrica Limited provided the GDP data.

The *Farm Energy Use Survey* conducted in 1997 by Statistics Canada also provides aggregate energy use data. Prior to this 1997 survey, however, a 16-year gap exists as Statistics Canada conducted its previous survey of farm energy use in Canada in 1981. As a result, Natural Resources Canada, along with Agriculture and Agri-Food Canada and Environment Canada, co-sponsored the 1997 *Farm Energy Use Survey.* The Canadian Agriculture Energy End-Use Data and Analysis Centre (CAEEDAC) will continue to concentrate its efforts on analysing the survey results over the coming year.

Information on the energy-using activities on Canadian farms is available only at an aggregate level. The agricultural GDP reported by Statistics Canada incorporates all agricultural activities, including both livestock and field crop productions, in its measure. Over the coming year, CAEEDAC will commence efforts to provide insights to disaggregate the information on the energy-using activities in the sector.

Data Presented in the Report

Figure A-1.3: The OEE Energy Efficiency Index 1990–1998 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
OEE Energy Efficiency Index	1.00	1.02	1.00	1.03	1.03	1.04	1.03	1.05	1.06

Source:

Natural Resources Canada, Office of Energy Efficiency. *Energy Efficiency Trends in Canada*, Sectoral compilation.

Figure A-2.1: Secondary Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Energy Use	1.00	0.98	1.00	1.02	1.06	1.07	1.11	1.11	1.09
Activity	1.00	0.98	0.99	1.01	1.06	1.08	1.09	1.14	1.17
Aggregate Energy Intensity	1.00	1.00	1.01	1.00	1.00	1.00	1.01	0.98	0.94
Energy Efficiency*	1.00	1.02	1.00	1.03	1.03	1.04	1.03	1.05	1.06

* This report presents the index of energy efficiency improvement while the previous report presented the index of energy efficiency effect on energy use.

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada. 1990–1998 revisions*, Ottawa, February 2000, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Informetrica Limited, *National Reference Forecast*, October 1999.

Figure A-2.2: Secondary Energy Fuel Shares, 1990 and 1998 (percent)

Fuel Types	1990	1998
Oil Products	36.6	36.4
Natural Gas	25.3	25.1
Electricity	22.1	22.2
Other Fuels (LPGs*, coal, coke & coke oven gases, steam, biomass)	16.0	16.3

* Liquified petroleum gas

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1998 revisions*, Ottawa, February 2000, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Figure A-3.1: Distribution of Floor Space by Type of Dwelling, 1998 (percent)

	1998
Mobile Homes	1.93
Apartments	23.40
Single-Attached	10.35
Single-Detached	64.33

Sources:

Statistics Canada, *Household Facilities and Equipment 1990–1997*, Ottawa, October 1990 – October 1997, (Cat. No. 64-202)

Statistics Canada, *Survey of Household Spending in 1998*, Ottawa, December 1999, (Cat. No. 62F0041)

Natural Resources Canada, *Survey of Household Energy Use, 1993 and 1997.*

Figure A-3.2: Distribution of Residential Energy Use by End-Use, 1998 (percent)

End-Uses	1998
Space Cooling	0.73
Water Heating	21.12
Appliances	14.22
Space Heating	59.55
Lighting	4.37

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Natural Resources Canada, *Residential End-Use Model*, Ottawa, March 2000.

Figure A-3.3: Residential Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 (index 1990 = 1.0)

Factors	1990	1991	1992	1993	1994	1995	1996	1997	1998
Energy Use	1.00	0.98	1.01	1.04	1.06	1.04	1.11	1.06	0.98
Aggregate Energy Intensity	1.00	0.96	0.96	0.98	0.98	0.95	1.00	0.93	0.84
Activity index	1.00	1.02	1.04	1.06	1.08	1.10	1.11	1.14	1.16
Energy Efficiency	1.00	1.05	1.08	1.07	1.06	1.10	1.07	1.11	1.12

* This report presents the index of energy efficiency improvement while the previous report presented the index of energy efficiency effect on energy use.

Sources:

Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days below 18.0°C*, Toronto, 1990–1998.

Statistics Canada, *Household Facilities and Equipment 1990–1997*, Ottawa, October 1990 – October 1997, (Cat. No. 64-202)

Statistics Canada, *Survey of Household Spending in 1998*, Ottawa, December 1999, (Cat. No. 62F0041)

Natural Resources Canada, *Survey of Household Energy Use, 1993 and 1997.*

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4). (Cat. No. 57-003)

Figure A-3.4: Residential Energy Fuel Shares, 1990 and 1998 (percent)

Fuel Types	1990	1998
Natural Gas	40.05	44.60
Electricity	35.43	36.22
Oil	14.13	9.76
Other Fuels (LPG's,* coal, steam, wood)	10.39	9.42

* Liquified petroleum gas

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4). (Cat. No. 57-003)

Figure A-3.5: Residential Energy End-Use Shares 1990 and 1998 (percent)

End-Uses	1990	1998
Space Cooling	0.45	0.73
Lighting	4.02	4.37
Appliances	14.06	14.22
Water Heating	19.57	21.12
Space Heating	61.90	59.55

Source:

Natural Resources Canada, *Residential End-Use Model*, Ottawa, March 2000.

Figure A-3.6: Average Floor Area of Dwellings by Vintage (square metre)

	Before 1946	1946–1960	1961–1977	1978–1983	1984–1995	1996–1997
Floor Area	126.80	111.44	124.29	133.70	150.53	145.11

Source:

Natural Resources Canada, *Survey of Household Energy Use, 1993 and 1997.*

Figure A-3.7: Households and Floor Area Evolution, 1990–1998 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Households	1.00	1.03	1.05	1.07	1.08	1.10	1.12	1.13	1.14
Floor area	1.00	1.02	1.04	1.06	1.08	1.10	1.11	1.15	1.17

Sources:

Statistics Canada, *Household Facilities and Equipment 1990–1997*, Ottawa, October 1990 – October 1997, (Cat. No. 64-202)

Statistics Canada, *Survey of Household Spending in 1998*, Ottawa, December 1999, (Cat. No. 62F0041)

Natural Resources Canada, *Survey of Household Energy Use, 1993 and 1997.*

Figure A-3.8: Factors Influencing Growth in Residential Energy Use, 1990–1998 (petajoules)

Factors	1990–1998
Energy Use	-31.75
Activity: Households or Floor Space	213.83
Weather	-68.11
Structure: End-Use Mix	16.28
Energy Efficiency*	-164.63
Interaction**	-29.23

* represents the effect of energy improvement over energy consumption

** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

Sources:

Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days below 18.0°C*, Toronto, 1990–1998.

Statistics Canada, *Household Facilities and Equipment 1990–1997*, Ottawa, October 1990 – October 1997, (Cat. No. 64-202)

Statistics Canada, *Survey of Household Spending in 1998*, Ottawa, December 1999, (Cat. No. 62F0041)

Natural Resources Canada, *Survey of Household Energy Use, 1993 and 1997.*

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4). (Cat. No. 57-003)

Natural Resources Canada, *Residential End-Use Model*, Ottawa, March 2000.

Figure A-3.9: Factors Influencing Growth in Residential Space Heating Energy Use, 1990–1998 (petajoules)

Factors	1990–1998
Energy Use	-49.88
Activity: Households or Floor Space	140.48
Weather	-68.11
Energy Efficiency*	-102.92
Interaction**	-19.33

* represents the effect of energy improvement over energy consumption

** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

Sources:

Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days below 18.0°C*, Toronto, 1990–1998.

Statistics Canada, *Household Facilities and Equipment 1990–1997*, Ottawa, October 1990 – October 1997, (Cat. No. 64-202)

Statistics Canada, *Survey of Household Spending in 1998*, Ottawa, December 1999, (Cat. No. 62F0041)

Natural Resources Canada, *Survey of Household Energy Use, 1993 and 1997.*

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Natural Resources Canada, *Residential End-Use Model*, Ottawa, March 2000.

Figure A-3.10: Housing Stock Floor Area by Vintage, 1990 and 1998 (percent)

	1990	1998
Pre-1946	19.98	16.52
1946–1960	13.53	11.33
1961–1977	34.47	28.89
1978–1983	13.61	11.45
Post-1983	18.41	31.81

Sources:

Statistics Canada, *Household Facilities and Equipment 1990–1997*, Ottawa, October 1990 – October 1997, (Cat. No.64-202)

Statistics Canada, *Survey of Household Spending in 1998*, Ottawa, December 1999, (Cat. No. 62F0041)

Natural Resources Canada, *Survey of Household Energy Use, 1993 and 1997.*

Figure A-3.11: Natural Gas Furnace Stocks by Efficiency Level, 1990 and 1998 (percent)

Efficiency Level	1990	1998
Normal Efficiency	92	78
Mid-Efficiency	2	13
High-Efficiency	5	10

Source:

Canadian Gas Association, *Canadian Gas Facts*, 1998, North York, 1998.

Figure A-3.12: Factors Influencing Growth in Residential Appliance Energy Use, 1990–1998 (petajoules)

Factors	1990–1998
Energy Use	-2.32
Activity: Households	26.42
Appliance Penetration	11.00
Energy Efficiency*	-34.44
Interaction**	-5.29

* represents the effect of energy improvement on energy consumption

** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

Sources:

Statistics Canada, *Household Facilities and Equipment 1990–1997*, Ottawa, October 1990 – October 1997, (Cat. No. 64-202)

Statistics Canada, *Survey of Household Spending in 1998*, Ottawa, December 1999, (Cat. No. 62F0041)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4).
(Cat. No. 57-003)

Figure A-3.13: Penetration Rate for Household Appliances, 1990 and 1998 (average number per household)

Appliances	1990	1998
Refrigerators	1.18	1.22
Electric Ranges	0.94	0.93
Microwave Ovens	0.64	0.86
Video Cassette Recorders	0.66	1.15
Clothes Washers	0.75	0.80
Electric Clothes Dryers	0.70	0.76
Freezers	0.57	0.59
Dishwashers	0.42	0.51
Compact Disc Players	0.15	0.67
Home Computers	0.16	0.45

Sources:

Statistics Canada, *Household Facilities and Equipment 1990–1997*, Ottawa, October 1990 – October 1997, (Cat. No. 64-202)

Statistics Canada, *Survey of Household Spending in 1998*, Ottawa, December 1999, (Cat. No. 62F0041)

Figure A-3.14: Energy Efficiency Trends of Appliances, 1990 and 1998 (kWh per year)

Appliances	1990	1998
Clothes Washers	1217.95	904.95
Clothes Dryers	1102.64	900.88
Refrigerators	956.17	664.00
Ranges	772.24	771.05
Freezers	713.78	395.37
Dishwashers	1025.65	647.99

Sources:

Natural Resources Canada, *EnerGuide Directories 1990*, Ottawa.

Natural Resources Canada, *EnerGuide Directories 1998*, Ottawa.

Canadian Appliances Manufacturers Association, 1998, Ottawa.

Figure A-3.15: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Residential Sector, 1990–1998 (percent)

	ES	NES
Greenhouse Gas Emissions	-0.75	-7.14
Energy Use	-2.41	-2.41
Greenhouse Gas Intensity	1.70	-4.85

ES: Electricity End-Use Emissions Scenario

NES: No Electricity End-Use Emissions Scenario

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Environment Canada, *Canada's Greenhouse Gas Inventory 1997*, Ottawa, April 1999, (EN49-8/5-9)

Natural Resources Canada, Residential End-Use Model, Ottawa, March 2000.

Figure A-3.16: Residential Greenhouse Gas Emissions by Fuel Type, 1998 (percent)

Fuel Types	1998
Electricity	41.56
Oil Products	13.34
Other Fuels	4.16
Natural Gas	40.94

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4). (Cat. No. 57-003)

Environment Canada, *Canada's Greenhouse Gas Inventory 1997*, Ottawa, April 1999, (EN49-8/5-9)

Natural Resources Canada, Residential End-Use Model, Ottawa, March 2000.

Figure A-3.17: Residential Greenhouse Gas Emissions by End-Use, 1990 and 1998 (percent)

End-Uses	1990	1998
Space Heating	60.33	56.28
Space Cooling	0.48	0.84
Water Heating	20.07	21.62
Appliances	14.86	16.25
Lighting	4.25	5.01

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Environment Canada, *Canada's Greenhouse Gas Inventory 1997*, Ottawa, April 1999, (EN49-8/5-9)

Natural Resources Canada, Residential End-Use Model, Ottawa, March 2000.

Figure A-3.18: Growth in Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, Residential Sector, 1990–1998 (percent)

	ES	NES
Carbon Dioxide Emissions	-0.57	-7.16
Energy Use	-2.41	-2.41
Carbon Dioxide Intensity	1.88	-4.87

ES: Electricity End-Use Emissions Scenario

NES: No Electricity End-Use Emissions Scenario

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Environment Canada, *Canada's Greenhouse Gas Inventory 1997*, Ottawa, April 1999, (EN49-8/5-9)

Figure A-3.19: Residential Carbon Dioxide Emissions by Fuel Type, 1998 (percent)

Fuels Types	1998
Electricity	42.68
Oil Products	13.77
Other Fuels	1.36
Natural Gas	42.20

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Environment Canada, *Canada's Greenhouse Gas Inventory 1997*, Ottawa, April 1999, (EN49-8/5-9)

Figure A-4.1: Distribution of Commercial Energy Use by End-Use, 1998 (percent)

End-Uses	1998
Space Heating	52.4
Lighting *	14.4
Auxiliary Motor	12.6
Auxiliary Equipment	7.1
Water Heating	7.6
Space Cooling	5.9

* Excludes street lighting

Sources:

Natural Resources Canada, Commercial End-Use Model, Ottawa, March 2000.

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Informetrica Limited, *Historical Estimates of Commercial Floor Space, 1998 Database Update*, Ottawa, June 1999.

Figure A-4.2: Distribution of Commercial Energy Use by Fuel Type, 1998 (percent)

Fuel Types	1998
Electricity	45.71
Natural Gas	44.16
Oil Products	6.78
LPG	3.17
Other	0.18

Sources:

Natural Resources Canada, Commercial End-Use Model, Ottawa, March 2000.

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Informetrica Limited, *Historical Estimates of Commercial Floor Space, 1998 Database Update,* Ottawa, June 1999.

Figure A-4.3: Distribution of Commercial Energy Use and Activity by Building Type, 1998 (percent)

Building Types	Energy Use	Activity
Retail	24.79	21.88
Office	24.23	27.96
School	13.62	14.73
Health	11.21	6.93
Hotel & Restaurant	8.92	5.65
Recreation	6.38	6.44
Warehouse	5.33	9.97
Other Institutional [a]	4.33	4.74
Religious	1.18	1.71

[a] Laboratory, research centre, library, museum

Sources:

Natural Resources Canada, Commercial End-Use Model, Ottawa, March 2000.

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Informetrica Limited, *Historical Estimates of Commercial Floor Space, 1998 Database Update,* Ottawa, June 1999.

Figure A-4.4: Commercial Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Energy Use *	1.00	1.03	1.04	1.08	1.07	1.11	1.13	1.15	1.09
Aggregate Energy Intensity	1.00	0.99	0.99	1.01	0.99	1.02	1.03	1.03	0.96
Activity: Floor Space	1.00	1.03	1.05	1.07	1.08	1.09	1.10	1.12	1.14
Energy Efficiency **	1.00	1.02	1.02	1.03	1.03	1.01	1.02	0.99	1.02

* In this figure, only energy use includes street lighting.
** This report presents an index of energy efficiency improvements while previous reports presented an index of the effects of energy efficiency on energy use.

Sources:

Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days above 18.0°C*, Toronto, 1990–1998.

Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days below 18.0°C*, Toronto, 1990–1998.

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Informetrica Limited, *Historical Estimates of Commercial Floor Space, 1998 Database Update*, Ottawa, June 1999.

Figure A-4.5: Factors Influencing Growth in Commercial Energy Use, 1990–1998 (petajoules)

Factors	1990–1998
Energy Use*	76.74
Activity: Floor Space	118.17
Weather	-19.60
Structure: Building Type	2.89
Energy Efficiency**	-17.78
Interaction***	-5.60

* In this figure, only energy use includes street lighting.
** Represents the effect of energy improvement on energy consumption.
*** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

Sources:

Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days above 18.0°C*, Toronto, 1990–1998.

Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days below 18.0°C*, Toronto, 1990–1998.

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Informetrica Limited, *Historical Estimates of Commercial Floor Space, 1998 Database Update*, Ottawa, June 1999.

Natural Resources Canada, Commercial End-Use Model, Ottawa, March 2000.

Figure A-4.6: Annual Growth of Commercial Floor Space and RDP with a 3-Year Lag (percent)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Activity (actual)	4.90	3.11	2.21	1.58	1.02	0.98	0.92	1.36	1.85
[a] RDP (3 years ago)	4.09	4.33	3.15	0.74	-0.16	1.06	2.06	2.69	1.59

[a] Real Domestic Product

Source:

Informetrica Limited, *Historical Estimates of Commercial Floor Space, 1998 Database Update*, Ottawa, June 1999.

Figure A-4.7: Changes in Commercial Activity Shares by Building Type, 1990–1998 (percentage points)

Building Types	1990–1998
Hotel/Restaurant	0.04
Health	-0.10
Retail	-1.80
Recreation	0.88
School	0.37
Other Institutional [a]	0.49
Office	1.96
Religious	-0.20
Warehouse	-1.65

[a] Laboratory, research centre, library, museum

Source:

Informetrica Limited, *Historical Estimates of Commercial Floor Space, 1998 Database Update*, Ottawa, June 1999.

Figure A-4.8: Commercial Sector Employment per Floor Space (thousands m^2)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Canada	20.20	19.54	19.23	19.30	19.47	19.49	19.62	19.70	19.86

Sources:

Informetrica Limited, *Historical Estimates of Commercial Floor Space, 1998 Database Update*, Ottawa, June 1999.

Statistics Canada, *Labour Force Survey*, Ottawa.

Figure A-4.9: Commercial Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Commercial Sector, 1990–1998 (percent)

	ES	NES
Greenhouse Gas Emissions	13.09	5.68
Energy Use	8.85	8.85
Greenhouse Gas Intensity	3.90	-2.91

ES: Electricity End-Use Emissions Scenario

NES: No Electricity End-Use Emissions Scenario

Sources:

Natural Resources Canada, Commercial End-Use Model, Ottawa, March 2000.

Environment Canada, *Canada's Greenhouse Gas Inventory 1997*, Ottawa, April 1999, (EN49-8/5-9)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Figure A-4.10: Commercial Energy Fuel Share, 1990 and 1998 (percent)

Fuel Types	1990	1998
Electricity	44.99	45.71
Natural Gas	44.65	44.16
Oil Products	8.46	6.78
LPGs*	1.85	3.17
Other Fuels (coal, steam)	0.05	0.18

* Liquified petroleum gas

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Figure A-4.11: Commercial Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, 1990–1998 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Greenhouse Gas Emissions	1.00	1.00	1.03	1.02	0.99	1.06	1.06	1.13	1.13
Energy Use	1.00	1.03	1.04	1.08	1.07	1.11	1.13	1.15	1.09
Greenhouse Gas Intensity	1.00	0.98	1.00	0.94	0.93	0.95	0.94	0.98	1.04

Sources:

Natural Resources Canada, Commercial End-Use Model, Ottawa, March 2000.

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Environment Canada, *Canada's Greenhouse Gas Inventory 1997*, Ottawa, April 1999, (EN49-8/5-9)

Figure A-5.1: Distribution of Energy Use and Activity (as measured by GDP) by Industry, 1998 (percent)

Industries	Energy Use	Activity
Metal Mines	2.60	2.56
Non-Metal Mines	1.51	0.57
Upstream Mining	10.81	12.12
Construction	1.60	16.45
Forestry	0.41	1.56
Pulp	12.67	0.88
Newsprint	8.85	1.59
Paperboard	2.55	0.81
Building Board	0.19	1.14
Other Paper	4.80	0.94
Primary Production of Aluminium	5.26	1.21
Other Non-Ferrous Smelting & Refining	2.59	0.60
Petroleum Refining	10.38	1.30
Cement	2.09	0.25
Industrial Inorganic Chemicals	2.72	0.58
Industrial Organic Chemicals	3.38	0.89
Chemical Fertilizer and Fertilizer Materials Industry	1.93	0.37
Iron & Steel	8.32	1.66
Food (excluding dairy)	2.57	6.56
Dairy Products	0.40	0.82
Beverage (excluding breweries)	0.21	1.58
Brewery Products	0.19	0.74
Tobacco Products	0.03	0.32
Rubber Products	0.35	0.99
Plastic Products	0.54	1.58
Leather & Allied Products	0.04	0.17
Primary Textile	0.44	0.69
Textile Products	0.28	0.62
Clothing	0.17	1.31
Wood	2.16	3.36
Furniture & Fixture	0.23	1.44
Printing, Publishing & Allied	0.35	2.63
Fabricated Metal Products	1.43	4.29
Machinery	0.49	2.37
Transportation Equipment	2.14	7.79
Electrical & Electronic Products	0.53	9.15
Glass & Glass Products	0.33	0.51
Lime	0.50	0.00
Plastic & Synthetic Resin	0.66	0.88
Other Manufacturing N.E.C.	3.30	6.74

Sources:

Informetrica Limited National Reference Forecast, Ottawa, October 1999

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998 revisions*, Ottawa, February 2000; (CANSIM)

Canadian Industrial Energy End-Use Data & Analysis Centre *Development of Energy Intensity Indicators for Canadian Industry 1990 to 1998*, Simon Fraser University, February 2000.

Figure A-5.2: Industrial Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Energy Use	1.00	0.98	0.99	1.00	1.06	1.08	1.11	1.11	1.10
Aggregate Energy Intensity	1.00	1.04	1.05	1.03	1.02	1.02	1.05	1.00	0.96
Activity: Gross Domestic Product	1.00	0.94	0.94	0.97	1.03	1.05	1.05	1.11	1.15
Energy Efficiency*	1.00	1.01	0.97	1.01	1.01	1.03	1.00	1.03	1.05

* This report presents the index of energy efficiency improvement while the previous report presented the index of energy efficiency effect on energy use.

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1998 revisions*, Ottawa, February 2000, (CANSIM)

Canadian Industrial Energy End-Use Data & Analysis Centre *Development of Energy Intensity Indicators for Canadian Industry 1990 to 1998*, Simon Fraser University, February 2000.

Informetrica Limited, *National Reference Forecast*, Ottawa, October 1999.

Figure A-5.3: Factors Influencing Growth in Industrial Energy Use, 1990–1998 (petajoules)

Factors	1990–1998
Energy Use	272.35
Activity: Gross Domestic Product & physical units of production	455.07
Structure: Sector Mix	61.80
Energy Efficiency*	-144.66
Interaction**	-99.87

* represents the effect of energy efficiency improvements on energy consumption

** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1998 revisions*, Ottawa, February 2000, (CANSIM)

Canadian Industrial Energy End-Use Data & Analysis Centre, *Development of Energy Intensity Indicators for Canadian Industry 1990 to 1998*, Simon Fraser University, February 2000.

Informetrica Limited, *National Reference Forecast*, Ottawa, October 1999.

Figure A-5.4: Changes in Sectoral Shares of Industrial Activity, 1990–1998 (percentage points)

Industries	Shares
Lime	N/A
Pulp	-0.05
Cement	-0.05
Petroleum Refining	-0.09
Newsprint	-0.37
Chemical Fertilizers & Fertilizer Materials	0.08
Other Paper	-0.15
Iron & Steel	0.01
Industrial Inorganic Chemicals	0.02
Primary Production of Aluminium	0.35
Other Non-Ferrous Smelting & Refining	-0.02
Industrial Organic Chemicals	-0.17
Paperboard	-0.28
Leather & Allied Products	-0.10
Non-Metal Mines	0.06
Metal Mines	-0.28
Upstream Mining	2.34
Plastic & Synthetic Resin	0.37
Wood	0.09
Primary Textile	0.03
Glass & Glass Products	0.13
Other Manufacturing N.E.C.	-1.06
Dairy Products	-0.23
Textile Products	-0.06
Food (excluding dairy)	0.27
Rubber Products	0.28
Plastic Products	0.33
Fabricated Metal Products	-0.04
Transportation Equipment	1.67
Forestry	-0.58
Brewery Products	-0.08
Machinery	-0.05
Building Board	0.38
Furniture & Fixture	0.39
Beverage (excluding breweries)	0.01
Printing, Publishing & Allied	-1.21
Clothing	-0.34
Tobacco Products	-0.08
Construction	-5.18
Electrical & Electronic Products	3.68

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1998 revisions*, Ottawa, February 2000, (CANSIM)

Canadian Industrial Energy End-Use Data & Analysis Centre *Development of Energy Intensity Indicators for Canadian Industry 1990 to 1998*, Simon Fraser University, February 2000.

Figure A-5.5: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Industrial Sector, 1990–1998 (percent)

	ES	NES
Greenhouse Gas Emissions	9.03	2.23
Energy Use	9.89	9.89
Greenhouse Gas Intensity	-0.78	-6.97

ES: Electricity end-use scenario

NES: No electricity end-use scenario

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1998 revisions*, Ottawa, February 2000, (CANSIM)

Environment Canada, *Canada's Greenhouse Gas Inventory, 1997 Emissions and Removal with Trends*, Ottawa, April 1999, (EN49-8/5-9)

Figure A-5.6: Industrial Greenhouse Gas Emissions by Industry, 1990 and 1998 (percent)

CO_2 Share Industries	1990	1998
Upstream Mining	9.15	13.22
Petroleum Refining	14.56	12.74
Iron & Steel	11.17	11.39
Newsprint	8.09	7.46
Primary Production of Aluminium	4.50	6.27
Pulp	4.53	4.32
Metal Mines	4.25	3.48
Other Non-Ferrous Smelting & Refining	3.24	3.41
Other Manufacturing N.E.C.	6.36	3.36
Industrial Organic Chemicals	3.71	3.36
Industrial Inorganic Chemicals	2.64	3.00
Cement	3.25	2.99
Food (excluding dairy)	2.81	2.70
Wood	1.44	2.44
Transportation Equipment	2.01	2.26
Construction	3.20	2.16
Chemical Fertilizers & Fertilizer Materials Industry	1.19	1.90
Other Paper	2.86	1.80
Paperboard	1.42	1.64
Non-Metal Mines	1.54	1.64
Fabricated Metal Products	1.02	1.49
Lime	0.72	0.70
Plastic Products	0.56	0.66
Forestry	0.43	0.63
Electrical & Electronic Products	0.69	0.58
Plastic & Synthetic Resin	0.62	0.57
Machinery	0.47	0.51
Dairy Products	0.46	0.43
Primary Textile	0.54	0.41
Rubber Products	0.37	0.39

(cont.)

Figure A-5.6: Industrial Greenhouse Gas Emissions by Industry, 1990 and 1998 (percent) (cont.)

CO_2 Share Industries	1990	1998
Printing, Publishing & Allied	0.32	0.38
Glass & Glass Products	0.45	0.33
Textile Products	0.25	0.26
Furniture & Fixture	0.19	0.26
Beverage (excluding breweries)	0.32	0.22
Brewery Products	0.27	0.19
Clothing	0.20	0.18
Building Board	0.09	0.16
Leather & Allied Products	0.05	0.04
Tobacco Products	0.05	0.04

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1998 revisions*, Ottawa, February 2000, (CANSIM)

Canadian Industrial Energy End-Use Data & Analysis Centre *Development of Energy Intensity Indicators for Canadian Industry 1990 to 1998*, Simon Fraser University, February 2000.

Environment Canada, *Canada's Greenhouse Gas Inventory 1997 Emissions and Removals with Trends*, Ottawa, April 1999, (EN49-8/5-9)

Figure A-5.7: Industrial Energy Fuel Shares, 1990 and 1998 (percent)

Fuel Types	1990	1998
Natural Gas	30.39	29.94
Other Fuels*	26.42	28.32
Electricity	23.90	25.37
Oil Products	12.88	10.54
Coal, Coke, Coke Oven Gas	6.40	5.82

* Other fuels include: petroleum coke, still gas, wood waste, pulping liquor, steam and waste fuels.

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1998 revisions*, Ottawa, February 2000, (CANSIM)

Canadian Industrial Energy End-Use Data & Analysis Centre *Development of Energy Intensity Indicators for Canadian Industry 1990 to 1998*, Simon Fraser University, February 2000.

Environment Canada, *Canada's Greenhouse Gas Inventory, 1997 Emissions and Removals with Trends*, Ottawa, April 1999, (EN49-8/5-9)

Figure A-5.8: Industrial Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, 1990–1998 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Greenhouse Gas Emissions	1.00	0.96	0.98	0.96	0.98	1.01	1.04	1.07	1.09
Energy Use	1.00	0.98	0.99	1.00	1.06	1.08	1.11	1.11	1.10
Greenhouse Gas Intensity	1.00	0.98	0.99	0.96	0.93	0.94	0.94	0.96	0.99

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1998 revisions*, Ottawa, February 2000, (CANSIM)

Environment Canada, *Canada's Greenhouse Gas Inventory, 1997 Emissions and Removals with Trends*, Ottawa, April 1999, (EN49-8/5-9)

Figure A-6.1: Distribution of Passenger Transportation Energy Use and Activity by Mode, 1998 (percent)

Modes	Energy Use*	Activity**
Road – Light Vehicles	77.23	74.85
Aviation	17.18	16.43
Road – Buses	5.34	8.46
Rail	0.17	0.25

* Includes non-commercial airline aviation.
** Measured in passenger-kilometres, excludes non-commercial airline aviation.

Sources:

Royal Commission on National Passenger Transportation, *Directions: the final report of the Royal Commission on National Passenger Transportation*, Ottawa, 1992; 2.

Statistics Canada, *Air Carrier Operations in Canada 1990–1994*, Ottawa, 1991–1995; 21(1) – 25(4), (Cat. No. 51-002)

Statistics Canada, *Aviation Statistics Centre: Service Bulletin*, Ottawa, 1990–1997; 22(1) – 29(12), (Cat. No. 51-004)

Statistics Canada, *Canadian Civil Aviation 1995–1997*, Ottawa,1996–1999, (Cat. No. 51-206)

Statistics Canada, *Passenger Bus and Urban Transit Statistics 1990–1997*, February 1993 – May 1999, (Cat. No. 53-215)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, *1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Statistics Canada, *Rail in Canada 1990–1997*, Ottawa, July 1992 – March 1999, (Cat. No. 52-216)

Natural Resources Canada, Transportation Energy Demand Model, Ottawa, August 1999.

Figure A-6.2: Distribution of Freight Transportation Energy Use and Activity by Mode, 1998 (percent)

Modes	Energy Use	Activity
Road – Freight Trucks	76.64	25.87
Marine	14.28	29.63
Rail	9.07	44.50

Sources:

Statistics Canada, *Air Carrier Operations in Canada 1990–1994*, Ottawa, 1991–1995; 21(1) – 25(4), (Cat. No. 51-002)

Statistics Canada, *Aviation Statistics Centre: Service Bulletin*, Ottawa, 1990–1997; 22(1) – 29(12), (Cat. No. 51-004)

Statistics Canada, *Canadian Civil Aviation 1995–1997*, Ottawa, 1996–1999, (Cat. No. 51-206)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, *1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Statistics Canada, *Rail in Canada 1990–1997*, Ottawa, July 1992 – March 1999, (Cat. No. 52-216)

Figure A-6.3: Passenger Transportation Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Energy Use*	1.00	0.96	0.98	0.99	1.03	1.04	1.05	1.07	1.10
Aggregate Energy Intensity**	1.00	0.98	0.97	0.99	0.99	0.98	0.98	0.97	0.99
Activity: Passenger-kilometre	1.00	0.98	1.02	1.01	1.04	1.07	1.08	1.11	1.12
Energy Efficiency***	1.00	1.02	1.03	1.01	1.01	1.02	1.02	1.03	1.01

* Includes non-commercial airline aviation.
** Excludes non-commercial airline aviation.
*** This report presents an index of energy efficiency improvements while previous reports presented an index of the effects of energy efficiency on energy use.

Sources:

Royal Commission on National Passenger Transportation, *Directions: the final report of the Royal Commission on National Passenger Transportation*,Ottawa, 1992; 2.

Statistics Canada, *Air Carrier Operations in Canada 1990–1994*, Ottawa, 1991–1995; 21(1) – 25(4), (Cat. No. 51-002)

Statistics Canada, *Aviation Statistics Centre: Service Bulletin*, Ottawa, 1990–1997; 22(1) – 29(12), (Cat. No. 51-004)

Statistics Canada, *Canadian Civil Aviation 1995–1997*, Ottawa, 1996–1999, (Cat. No. 51-206)

Statistics Canada, *Passenger Bus and Urban Transit Statistics 1990–1997*, February 1993 – May 1999, (Cat. No. 53-215)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Statistics Canada, *Rail in Canada 1990–1997*, Ottawa, July 1992 – March 1999, (Cat. No. 52-216)

Figure A-6.4: Passenger Transportation Fuel Shares, 1990 and 1998 (percent)

Fuel Types	1990	1998
Motor Gasoline	76.12	75.77
Aviation Fuels	16.04	17.17
Diesel	6.11	5.67
Alternative Transportation Fuels*	1.73	1.38

* Includes propane, natural gas and electricity

Sources:

Natural Resources Canada, Transportation Energy Demand Model, Ottawa, August 1999.

Statistics Canada, *Air Carrier Operations in Canada 1990–1994*, Ottawa, 1991–1995; 21(1) – 25(4), (Cat. No. 51-002)

Statistics Canada, *Aviation Statistics Centre: Service Bulletin*, Ottawa, 1990–1997; 22(1) – 29(12), (Cat. No. 51-004)

Statistics Canada, *Canadian Civil Aviation 1995–1997*, Ottawa, 1996–1999, (Cat. No. 51-206)

Statistics Canada, *Passenger Bus and Urban Transit Statistics 1990–1997*, February 1993 – May 1999, (Cat. No. 53-215)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Statistics Canada, *Rail in Canada 1990–1997*, Ottawa, July 1992 – March 1999, (Cat. No. 52-216)

Figure A-6.5: Passenger Transportation Energy Mode Shares, 1990 and 1998 (percent)

Modes	1990	1998
Road – Light Vehicles	77.65	77.23
Aviation	16.04	17.17
Road – Buses	5.88	5.43
Rail	0.43	0.17

Sources:

Natural Resources Canada, Transportation Energy Demand Model, Ottawa, August 1999.

Statistics Canada, *Air Carrier Operations in Canada 1990–1994*, Ottawa, 1991–1995; 21(1) – 25(4), (Cat. No. 51-002)

Statistics Canada, *Aviation Statistics Centre: Service Bulletin*, Ottawa, 1990–1997; 22(1) – 29(12), (Cat. No. 51-004)

Statistics Canada, *Canadian Civil Aviation 1995–1997*, Ottawa, 1996–1999, (Cat. No. 51-206)

Statistics Canada, *Passenger Bus and Urban Transit Statistics 1990–1997*, February 1993 – May 1999, (Cat. No. 53-215)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Statistics Canada, *Rail in Canada 1990–1997*, Ottawa, July 1992 – March 1999, (Cat. No. 52-216)

Figure A-6.6: Factors Influencing Growth in Passenger Transportation Energy Use, 1990–1998 (petajoules)

Factors	1990–1998
Energy Use	115.96
Activity: Passenger-kilometre	134.19
Structure: Vehicle Mix	1.94
Energy Efficiency*	-7.33
Interaction**	-4.08

* Represents the effect of energy improvements on energy consumption.
** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.
Note: The factorization excludes non-commercial airline aviation (8.8 PJ)

Sources:

Royal Commission on National Passenger Transportation, *Directions: the final report of the Royal Commission on National Passenger Transportation*, Ottawa, 1992; 2.

Statistics Canada, *Air Carrier Operations in Canada 1990–1994*, Ottawa, 1991–1995; 21(1) – 25(4), (Cat. No. 51-002)

Statistics Canada, *Aviation Statistics Centre: Service Bulletin*, Ottawa, 1990–1997; 22(1) – 29(12), (Cat. No. 51-004)

Statistics Canada, *Canadian Civil Aviation 1995–1997*, Ottawa, 1996–1999, (Cat. No. 51-206)

Statistics Canada, *Passenger Bus and Urban Transit Statistics 1990–1997*, February 1993 – May 1999, (Cat. No. 53-215)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Statistics Canada, *Rail in Canada 1990–1997*, Ottawa, July 1992 – March 1999, (Cat. No. 52-216)

Natural Resources Canada, Transportation Energy Demand Model, Ottawa, August 1999.

Figure A-6.7: Factors Influencing Growth in Light Vehicle Passenger Transportation Energy Use, 1990–1998 (petajoules)

Factors	1990–1998
Energy Use	84.69
Activity: Passenger-kilometre	74.91
Structure: Vehicle Mix	35.87
Energy Efficiency*	-34.60
Interaction**	8.50

* represents the effect of energy improvements on energy consumption
** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

Sources:

Royal Commission on National Passenger Transportation, *Directions: the final report of the Royal Commission on National Passenger Transportation*, Ottawa, 1992; 2.

Statistics Canada, *Air Carrier Operations in Canada 1990–1994*, Ottawa, 1991–1995; 21(1) – 25(4), (Cat. No. 51-002)

Statistics Canada, *Aviation Statistics Centre: Service Bulletin*, Ottawa, 1990–1997; 22(1) – 29(12), (Cat. No. 51-004)

Statistics Canada, *Canadian Civil Aviation 1995–1997*, Ottawa, 1996–1999, (Cat. No. 51-206)

Statistics Canada, *Passenger Bus and Urban Transit Statistics 1990–1997*, February 1993 – May 1999, (Cat. No. 53-215)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions,* Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Statistics Canada, *Rail in Canada 1990–1997*, Ottawa, July 1992 – March 1999, (Cat. No. 52-216)

Natural Resources Canada, Transportation Energy Demand Model, Ottawa, August 1999.

Figure A-6.8: New Passenger Car Fuel Economy, Normalized for Weight and Power, 1990–1998 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
L/100 km	1.00	0.98	0.99	0.99	1.00	0.97	0.96	0.98	0.98
L/100 km / kg	1.00	0.97	0.98	0.97	0.96	0.92	0.92	0.93	0.93
L/100 km / Hp	1.00	0.96	0.93	0.91	0.90	0.83	0.81	0.81	0.80

Sources:

Transport Canada Vehicles Fuel Economy Informetrica System, Ottawa, May 2000.

Natural Resources Canada – Vehicles Information System, Ottawa, May 2000.

Figure A-6.9: Freight Transportation Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Energy Use	1.00	0.97	0.99	1.01	1.08	1.11	1.14	1.22	1.26
Aggregate Energy Intensity	1.00	0.98	1.04	1.02	0.99	0.99	0.99	0.99	1.02
Activity: Tonne-kilometre	1.00	0.99	0.95	0.98	1.10	1.13	1.16	1.23	1.24
Energy Efficiency*	1.00	0.98	0.97	1.03	1.09	1.11	1.15	1.15	1.15

* This report presents an index of energy efficiency improvements while previous reports presented an index of the effects of energy efficiency on energy use.

Sources:

Natural Resources Canada, Transportation Energy Demand Model, Ottawa, August 1999.

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Statistics Canada, *Rail in Canada 1990–1997*, Ottawa, July 1992 – March 1999, (Cat. No. 52-216)

Transport Canada, *Surface Marine and Statistics and Forecast Division*, Personal Communication, March 1999.

Statistics Canada, *Shipping in Canada 1990–1997*, Ottawa, March 1992 – April 1999, (Cat. No. 54-205)

Statistics Canada, *Trucking in Canada 1990*, Ottawa, February 1993, (Cat. No. 53-222)

Statistics Canada, *Trucking in Canada 1997,* Ottawa, February 1999, (Cat. No. 53-222)

Figure A-6.10: Freight Transportation Fuel Shares, 1990 and 1998 (percent)

Fuel Types	1990	1998
Diesel	60.70	64.39
Motor Gasoline	27.10	24.93
Heavy Fuel Oil	9.16	8.87
Other Fuels (propane, natural gas, coal, kerosene and LFO*)	3.04	1.80

* Light Fuel Oil

Sources:

Natural Resources Canada, Transportation Energy Demand Model, Ottawa, August 1999.

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Statistics Canada, *Rail in Canada 1990–1997*, Ottawa, July 1992 – March 1999, (Cat. No. 52-216)

Figure A-6.11: Factors Influencing Growth in Freight Transportation Energy Use, 1990–1998 (petajoules)

Factors	1990–1998
Energy Use	171.83
Activity: Tonne-kilometre	158.51
Structure: Vehicle Mix	131.78
Energy Efficiency*	-95.81
Interaction**	-22.66

* represents the effect of energy improvements on energy consumption
** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Statistics Canada, *Rail in Canada 1990–1997*, Ottawa, July 1992 – March 1999, (Cat. No. 52-216)

Transport Canada, *Surface Marine and Statistics and Forecast Division,* Personal Communication, March 1999.

Statistics Canada, *Trucking in Canada 1990*, Ottawa, February 1993, (Cat. No. 53-222)

Statistics Canada, *Trucking in Canada 1997*, Ottawa, February 1999, (Cat. No. 53-222)

Figure A-6.12: Factors Influencing Growth in Road Freight Transportation Energy Use, 1990–1998 (petajoules)

Factors	1990–1998
Energy Use	169.35
Activity: Tonne-kilometre	298.03
Structure: Vehicle Mix	-35.28
Energy Efficiency*	-43.13
Interaction**	-50.27

* represents the effect of energy improvements on energy consumption

** For an explanation of this term, see the section called "Notes on Interaction Terms" in Appendix C.

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Statistics Canada, *Rail in Canada 1990–1997*, Ottawa, July 1992 – March 1999, (Cat. No. 52-216)

Statistics Canada, *Trucking in Canada 1990*, Ottawa, February 1993, (Cat. No. 53-222)

Statistics Canada, *Trucking in Canada 1997*, Ottawa, February 1999, (Cat. No. 53-222)

Figure A-6.13: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Transportation Sector, 1990–1998 (percent)

	1990–1998
Greenhouse Gas Emissions	16.24
Energy Use	16.19
Greenhouse Gas Intensity	0.04

Sources:

Environment Canada, *Canada's Greenhouse Gas Inventory 1997*, Ottawa, April 1999, (EN49-8/5-9)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Figure A-6.14: Transportation Greenhouse Gas Emissions Shares by Mode, 1990 and 1998 (percent)

Modes	1990	1998
Road – Light Vehicle	47.73	45.04
Road – Freight Trucks	24.60	28.91
Aviation	10.03	10.15
Marine	6.03	5.74
Rail	5.26	3.91
Road – Buses	3.58	3.12
Off-Road	2.77	3.11

Sources:

Environment Canada, *Canada's Greenhouse Gas Inventory 1997*, Ottawa, April 1999, (EN49-8/5-9)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Figure A-6.15: Transportation Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, 1990–1998 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Greenhouse Gas Emissions	1.00	0.96	0.98	1.00	1.05	1.07	1.09	1.13	1.16
Energy Use	1.00	0.96	0.99	1.00	1.05	1.07	1.09	1.13	1.16
Greenhouse Gas Intensity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Sources:

Environment Canada, *Canada's Greenhouse Gas Inventory 1997*, Ottawa, April 1999, (EN49-8/5-9)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Figure A-7.1: Distribution of Agricultural Energy Use by Fuel Type, 1998 (percent)

Fuel Types	1998
Diesel Fuel Oil	44.91
Motor Gasoline	20.45
Electricity	15.35
Natural Gas	10.58
Other RPP[a]	6.45
Other Fuels[b]	2.26

[a] Refined petroleum products
[b] Propane, steam

Source:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Figure A-7.2: Agricultural Energy Use, Aggregate Energy Intensity, Activity and Energy Efficiency, 1990–1998 (Index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Energy Use	1.00	0.98	0.99	1.00	0.98	1.05	1.12	1.16	1.13
Activity: Gross Domestic Product	1.00	0.99	0.93	0.99	1.03	1.06	1.10	1.09	1.08
Aggregate Energy Intensity	1.00	0.99	1.07	1.01	0.95	1.00	1.02	1.06	1.04

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Informetrica Limited, *National Reference Forecast*, Ottawa, October 1999

Figure A-7.3: Agricultural Energy Fuel Shares, 1990 and 1998 (percent)

Fuel Types	1990	1998
Diesel Fuel Oil	35.91	44.91
Motor Gasoline	28.15	20.45
Electricity	15.61	15.35
Natural Gas	11.63	10.58
Other Refined Petroleum Products [a]	6.19	6.45
Other Fuels [b]	2.50	2.26

[a] Refined petroleum products
[b] Propane, steam

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Figure A-7.4: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Agricultural Sector, 1990–1998 (percent)

	ES	NES
Greenhouse Gas Emissions	15.89	14.99
Energy Use	12.80	12.80
Greenhouse Gas Intensity	2.74	1.94

ES: Electricity End-Use Emission Scenario

NES: No End-Use Emissions Scenario

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Environment Canada, *Canada's Greenhouse Gas Inventory 1997*, Ottawa, April 1999, (EN49-8/5-9)

Figure A-7.5: Agriculture Greenhouse Gas Emissions by End Use, 1998 (percent)

End-Uses	1998
Other Fuels	8.57
Natural Gas	7.37
Electricity	13.37
Motor Gasoline	20.33
Diesel Fuel Oil	50.37

Sources:

Environment Canada, *Canada's Greenhouse Gas Inventory 1997*, Ottawa, April 1999, (EN49-8/5-9)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Figure A-7.6: Growth in Greenhouse Gas Emissions, Energy Use and Greenhouse Gas Intensity, Agriculture Sector, 1990–1998 (Index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Greenhouse Gas Emissions	1.00	0.97	0.98	0.97	0.97	1.05	1.11	1.16	1.16
Energy Use	1.00	0.98	0.99	1.00	0.98	1.05	1.12	1.16	1.13
Greenhouse Gas Intensity	1.00	0.99	0.99	0.97	0.98	0.99	0.99	1.01	1.03

Sources:

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1990–1997 revisions*, Ottawa, July 1999, (CANSIM)

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada, 1998*, Ottawa, December 1999; 23(4), (Cat. No. 57-003)

Environment Canada, *Canada's Greenhouse Gas Inventory 1997*, Ottawa, April 1999, (EN49-8/5-9)

Types of Indicators

This report uses a variety of indicator types to explain the role of energy efficiency in the evolution of secondary energy use and emissions. An indicator is an index or any group of statistical values. For example, the level of employment is an economic indicator that gives an indication of the health of the economy. Energy use indicators measure the status of a specific segment of the economy. Indicators are often structured hierarchically from the most aggregate to the most disaggregate to provide a link between what we observe and the reasons for what we observe. The challenge is to improve these linkages.

The indicators used in this report have been categorized into two major types: factual and analytical.

Factual Indicators

Factual indicators are used to describe a situation. For example, how much energy is used and where it is used or the level of emissions in a given sector. Factual indicators can be further categorized into two types: snapshot and trend, according to the time dimension they portray. Snapshot indicators describe a situation at a point in time, while trend indicators describe the evolution of a situation over time.

Analytical Indicators

Analytical indicators are used to explain a situation. The two types of analytical indicators used extensively in this report are factorial and causal indicators. Factorial indicators are based upon an analysis of time series data where the source of change in one variable is attributed to the principal factors affecting that change. In this report, this approach has been applied to the change in energy use in each sector and, in so doing, has attributed to activity, structure, weather and energy intensity a contribution to the change in energy use. This factorization methodology is described in more detail below and in Appendix C.

Causal indicators are also used to explain change in a particular variable. For example, energy price is a causal indicator that can explain change in the level of energy use. Factorial indicators are also causal; the two types are distinguished in this report to emphasize the fact that the "causes" highlighted in the factorization analysis are strictly and quantitatively related to the factor being explained, in this case the change in energy use. To explain cause and effect in other instances, a more casual approach of qualitatively contrasting the trend in causal analytical indicators with the trend in the variable being explained is used. Table 1.1 illustrates the different types of indicators used in this report.

Table 1.1: Illustration of the Types of Indicators Used in This Report

Factual	Analytical
Snapshot	Factorial
- households by type of dwelling, 1998 - energy use by type of dwelling, 1998 - energy use by end-use, 1998	- activity effect, 1990 to 1998 - structure effect (end-use mix), 1990 to 1998 - energy intensity effect, 1990 to 1998
Trend	Causal
- degree-day index, 1990 to 1998 - energy intensity index, 1990 to 1998 - energy use index, 1990 to 1998	- housing stock by vintage, 1990 and 1998 - gas furnace shipments by efficiency, 1990 and 1998 - degree-day index, 1990 to 1998

Methodology and Data Sources for the Energy Use Factorization Analysis

1 Introduction

This appendix describes the key elements of the methodology that was used in this study to analyse secondary energy end-use trends in the Canadian economy as a whole and in each of the five end-use sectors. Four important criteria determined the choice of methodology[1] used in this analysis:

- Interpretation of the index must be straightforward.
- The same index must be applicable to all sectors and sub-sectors so that all can be interpreted similarly.
- Data must be available with which to calculate the indexes.
- The index must be theoretically sound.

In the simplest terms, an energy index is a statistical indicator that measures energy use, taking account of changes in energy efficiency,[2] structural influences and economic or physical activity. Such indicators can be applied to measure energy consumption at the economy-wide level, in individual sectors (e.g., transportation, commercial), industries (e.g., forestry, pulp and paper) and specific end-uses (e.g., space heating, refrigeration). The basic formulation, a Laspeyres factorization method, has been used extensively in international comparisons of energy use.

2 The Factorization Method

The simple ratio of gross domestic product (GDP) to energy is an imperfect indicator of the overall energy efficiency of the economy. Both structural changes in the economy and changes in technical energy efficiency can change the GDP/energy indicator. For example, because the industrial sector is more energy-intensive than other sectors, it would contribute to a higher GDP/energy ratio if its GDP increased in relation to energy use, even if the technical energy efficiency remained unchanged.

To isolate improvements in energy efficiency, an energy index is used. This index is a statistical indicator that measures energy use, taking account of changes in energy efficiency, structural influences and economic or physical activity.

The development of the indexes is based on the following identity.

$$E = A\frac{E}{A} = A\Omega$$

where E is energy use, and A is the level of activity. The quantity Ω is the intensity of energy use per unit of activity.

1 B. Jenness, M. Haney and A. Storey. *Energy Efficiency Indicators: Conceptual Framework and Data Sources.* Prepared by Informetrica Limited for Natural Resources Canada, March 31, 1995.

2 Changes in energy intensity are used to approximate changes in energy efficiency.

The following section develops indexes that characterize different influences on the movements in aggregate energy use. For an energy-consuming sector that is composed of several sub-sectors (e.g., industry, can be broken down in to steel, transportation manufacturing, pulp and paper, etc.), movements in aggregate energy can be due to changes in the mix of activity of its sub-sectors (e.g., more steel may be produced one year while pulp and paper production decreases) or due to changes in the intensity of energy use of its sub-sectors. The relationship between aggregate energy use in a sector and those of its sub-sectors is as follows:

$$E = \sum_i E_i = \sum_i A_i \Omega_i$$

where the subscript "i" denotes the "ith" sub-sector.

Aggregate activity effects are separated from activity-mix effects between sectors through the following equation:

$$E = A \sum_i a_i \Omega_i$$

where "a_i" is the activity share of the "ith" sub-sector (see the section "Activity in the Industrial Sector" for exceptions relating to industry). That is expressed as follows:

$$a_i = \frac{A_i}{A}$$

The basic energy identity then is the following:

$$E = A \sum_i a_i \Omega_i$$

To denote time, a subscript of "$_0$" is used for base-period values and the absence of the "$_0$" subscript is used for current period values. For example, the identity above, in index form, becomes the following:

$$\frac{E}{E_0} = \frac{A \sum_i a_i \Omega_i}{A \sum_i a_{i0} \Omega_{i0}}$$

Factorization of Energy

The energy index is the product of the activity and average intensity indexes:

$$\frac{E}{E_0} = \frac{A}{A_0}\frac{\Omega}{\Omega_0}$$

Using the identity

$$xy - 1 = (x - 1) + (y - 1) + (x - 1)(y - 1)$$

the *change* in the energy index can be expressed as the sum of the changes in activity and average intensity indexes plus an interaction term, as follows:

$$\frac{E}{E_0} - 1 = \left(\frac{A}{A_0} - 1\right) + \left(\frac{\Omega}{\Omega_0} - 1\right) + \left(\frac{A}{A_0} - 1\right)\left(\frac{\Omega}{\Omega_0} - 1\right)$$

For brevity, the interaction term is denoted as "ε".

The Structure and Intensity Indexes

The average intensity index is defined in terms of its sub-sector activity shares and intensities as follows:

$$\frac{\Omega}{\Omega_0} = \frac{\sum_i a_i \Omega_i}{\sum_i a_{i0} \Omega_{i0}}$$

Movements in the average sector intensity consist of movements in activity shares and in the intensities of the sub-sectors. To isolate these effects, two other indexes are defined. Each index uses the same formula as above but holds one of the quantities fixed at base-period values.

The "pure" structure index is defined as follows:

$$\frac{S}{S_0} = \frac{\sum_i a_i \Omega_{io}}{\sum_i a_{i0} \Omega_{i0}}$$

This measures what the sector's average intensity would have been had its sub-sectors' *intensities* remained fixed at base-period values.

Similarly, the "pure" intensity index is defined as follows:

$$\frac{I}{I_0} = \frac{\sum_i a_{i0} \Omega_i}{\sum_i a_{i0} \Omega_{i0}}$$

This measures what the sector's average intensity would have been had its sub-sectors' *activity shares* remained fixed at base-period values. Throughout this report, changes in the "pure" intensity index are used to approximate changes in "pure" energy efficiency. Energy intensity represents the amount of energy input required for a given amount of activity and energy efficiency represents the amount of activity that can be derived from a given amount of energy. Thus change in energy intensity is a good approximation of the inverse change in energy efficiency.

The Base-Weighted Form of the Indexes

Before introducing the factorization of the average intensity into its structure and "pure" intensity components, it should be noted that the structure and intensity indexes have a simple representation as the base-period, energy weighted sum of simple indexes.

The structure index can be represented by the following equation:

$$\frac{S}{S_0} = \frac{\sum_i a_{i0}\Omega_{io}\frac{a_i}{a_{i0}}}{\sum_i a_{i0}\Omega_{i0}}$$

The following simplification is made.

$$\frac{a_{i0}\Omega_{io}}{\sum_i a_{i0}\Omega_{i0}} = \frac{E_{i0}/A_0}{E_0/A_0} = \frac{E_{i0}}{E_0} = b_i$$

where "b_i" is the base-period energy share of the "ith" sub-sector. (Note the subscript "$_0$" is not used for "b_i" – this notation will always refer to the base-period energy share.) This yields the following representation of the structure index:

$$\frac{S}{S_0} = \sum_i b_i \frac{a_i}{a_{i0}}$$

That is, the structure index is the base-period, energy-share weighted sum of the sub-sector – activity share indexes.

Following the same methodology, the "pure" intensity index is represented as follows:

$$\frac{I}{I_0} = \sum_i b_i \frac{\Omega_i}{\Omega_{i0}}$$

which is simply the base-period, energy-share weighted sum of the sub-sector *average* intensity indexes. (Note that the "pure" intensity index is *not* the weighted sum of the sub-sector "pure" intensity indexes. The "pure" intensity index will be denoted by "I" and average intensity index by Ω.)

Since the base-period weights sum to unity, the above two formulas also hold in the index-change form. In particular:

$$\frac{S}{S_0}-1=\sum_i b_i\left(\frac{a_i}{a_{i0}}-1\right) \qquad \frac{I}{I_0}-1=\sum_i b_i\left(\frac{\Omega_i}{\Omega_{i0}}-1\right)$$

Factorization of Intensity into Structure and "Pure" Intensity

To demonstrate the relationship between the average intensity index and the structure and "pure" intensity indexes, the same device is used as in the previous section. That is:

$$\frac{\Omega}{\Omega_0}=\frac{\sum_i a_i\Omega_i}{\sum_i a_{i0}\Omega_{i0}}=\frac{\sum_i a_{i0}\Omega_{i0}\frac{a_i}{a_{i0}}\frac{\Omega_i}{\Omega_{i0}}}{\sum_i a_{i0}\Omega_{i0}}=\sum_i b_i\frac{a_i}{a_{i0}}\frac{\Omega_i}{\Omega_{i0}}$$

Since the base-period energy shares sum to unity, the above can be written in change form as:

$$\frac{\Omega}{\Omega_0}-1=\sum_i b_i\left(\frac{a_i}{a_{i0}}\frac{\Omega_i}{\Omega_{i0}}-1\right)$$

The quantity in parentheses is the change in the product of two indexes, so it can be factored (as was done with the total energy index) as follows:

$$\frac{\Omega}{\Omega_0}-1=\sum_i b_i\left(\frac{a_i}{a_{i0}}-1\right)+\sum_i b_i\left(\frac{\Omega_i}{\Omega_{i0}}-1\right)+\sum_i b_i\left(\frac{a_i}{a_{i0}}-1\right)\left(\frac{\Omega_i}{\Omega_{i0}}-1\right)$$

This demonstrates the relationship sought: the first sum is the structure index and the second is the "pure" intensity index. The third term – which is a sum of "interaction terms" – will be denoted by "δ". So changes in the average intensity index are related to the two other indexes as follows:

$$\frac{\Omega}{\Omega_0}-1=\left(\frac{S}{S_0}-1\right)+\left(\frac{I}{I_0}-1\right)+\delta$$

This completes the factorization of the total energy index:

$$\frac{E}{E_0}-1=\left(\frac{A}{A_0}-1\right)+\left(\frac{\Omega}{\Omega_0}-1\right)+\varepsilon=\left(\frac{A}{A_0}-1\right)+\left(\frac{S}{S_0}-1\right)+\left(\frac{I}{I_0}-1\right)+\delta+\varepsilon$$

where, as before, ε is the intensity-activity interaction term, and δ is the structure-intensity interaction term.

The following notation is introduced to support the next section. From the definition of ε (and the factorization formula) for average intensity, the following is known:

$$\varepsilon=\left(\frac{A}{A_0}-1\right)\left(\frac{\Omega}{\Omega_0}-1\right)=\left(\frac{A}{A_0}-1\right)\left[\left(\frac{S}{S_0}-1\right)+\left(\frac{I}{I_0}-1\right)+\delta\right]$$

therefore ε can be represented as the sum of the three following “interaction terms”:

$$\varepsilon_1 = \left(\frac{A}{A_0}-1\right)\left(\frac{S}{S_0}-1\right) = \left(\frac{A}{A_0}-1\right)\sum_i b_i\left(\frac{a_i}{a_{i0}}-1\right)$$

$$\varepsilon_2 = \left(\frac{A}{A_0}-1\right)\left(\frac{I}{I_0}-1\right) = \left(\frac{A}{A_0}-1\right)\sum_i b_i\left(\frac{\Omega_i}{\Omega_{i0}}-1\right)$$

$$\varepsilon_3 = \left(\frac{A}{A_0}-1\right)\delta = \left(\frac{A}{A_0}-1\right)\sum_i b_i\left(\frac{a_i}{a_{i0}}-1\right)\left(\frac{\Omega_i}{\Omega_{i0}}-1\right)$$

These three terms are used in the development of the next section.

Two-Way Factorization of Total Energy

The factorization of a sector’s energy index into activity, structure and intensity indexes (with attendant interaction terms) provides measures that summarize different influences on the movements of the total energy index. However, the individual contributions of the sub-sectors to each of these indexes is also of interest. For example, if we observe movements in the intensity index, it is useful to know which sub-sectors are contributing to the movement, and in which direction. This is true, even if there are no movements in the aggregate index, since this may be due to offsetting contributions of the sub-sectors.

The sub-sector composition of the change in the aggregate indexes can also reveal useful patterns both between sub-sectors and between aggregate indexes. For example, it may reveal that one set of sub-sectors is moving the aggregate energy index via the structure and activity indexes, while a different set of sub-sectors is moving the energy index via the intensity index.

These considerations motivate the development of the "two-way" decomposition formulas that are described in this section.

Note the following equation:

$$\frac{E}{E_0} = \sum_i \frac{E_{i0}}{E_0}\frac{E_i}{E_{i0}} = \sum_i b_i \frac{E_i}{E_{i0}}$$

or, in the index change form, this equation:

$$\frac{E}{E_0} - 1 = \sum_i b_i\left(\frac{E_i}{E_{i0}}-1\right)$$

Thus, an individual sub-sector's (total) contribution to the change in the sector's total energy index is simply the change in its own energy index multiply by its base-period energy share.

Note that the change in the sub-sectors energy index can be represented as follows:

$$\frac{E}{E_0} - 1 = \frac{A}{A_0}\frac{a_i}{a_{i0}}\frac{\Omega_i}{\Omega_{i0}} - 1$$

Factoring the product twice yields the following result:

$$\frac{E}{E_0} - 1 = \left(\frac{A}{A_0} - 1\right) + \left(\frac{a_i}{a_{i0}} - 1\right) + \left(\frac{\Omega_i}{\Omega_{i0}} - 1\right) + \left(\frac{a_i}{a_{i0}} - 1\right)\left(\frac{\Omega_i}{\Omega_{i0}} - 1\right) + \left(\frac{A}{A_0} - 1\right)\left(\frac{a_i}{a_{i0}} - 1\right) + \left(\frac{A}{A_0} - 1\right)\left(\frac{\Omega_i}{\Omega_{i0}} - 1\right) + \left(\frac{A}{A_0} - 1\right)\left(\frac{a_i}{a_{i0}} - 1\right)\left(\frac{\Omega_i}{\Omega_{i0}} - 1\right)$$

Multiplying this equation through by b_i and summing over i each of the sums on the right-hand side adds to, respectively, the change in the total sector activity index, the change in the structure index and the change in the "pure" intensity index, δ, ε_1, ε_2 and ε_3.

This completes the two-way factorization of the changes in the total energy index. The factorization yields values for the following table:

	Total Energy	Activity	Structure	Energy Efficiency[3]	Interaction Terms
Sector Total					
Contributions of:					
sub-sector 1					
sub-sector 2					
…					
sub-sector n					

This schematic represents the analytical framework used for studying movements in the various aggregate indexes at a given level of the "pyramid" (each sector's "pyramid" is defined later in this appendix). Interesting observations in any sub-sector row of the table can be drawn by proceeding to the next level of the pyramid.

Activity in the Industrial Sector

Activity is treated differently in the residential and industrial sectors than in the other three sectors. In the other sectors, activity and the growth in activity are measured in units that are homogenous across the sub-sectors within those sectors. For instance, in the commercial sector, activity is measured by floor space, and all floor space is assumed to be equivalent.

In the residential sector, activity can be measured by the number of households or by the floor area of houses. In this report, both indicators are used as activity indicators. Floor area is used when analyzing space heating, space cooling and lighting, while the number of households is used when looking at appliances and water heating.

3 Approximated by energy intensity.

Since floor area and the number of households cannot be summed up together, a methodology was developed in order to get factorization results for the whole residential sector. The methodology provides results for each of the five end-uses (space heating, space cooling, lighting, appliances, water heating). Results are also available for two sub-sectors; floor space services (which include space heating, space cooling and lighting and are based on floor area) and household services (which include appliances and water heating). To get results for the whole sector, the factorization results for the two sub-sectors are weighted according to their share of total residential energy use and then added together.

In the industrial sector, the best measure of activity is physical units of production (e.g., tonnes of steel, hectolitres of beer, etc.). These physical units are not comparable, so a common homogenous base is required so that values for activity can be summed across industries. GDP is such a common factor. As a measure of value added, it has the desirable effect that it can be added across industries. Unfortunately, as prices change, the relationship between GDP and physical units (the better indicator of activity) can change. This makes GDP an imperfect indicator of physical units of production. To reduce the impact of these price effects, an industry's share of activity has been denoted by the following equation:

$$a_i = \frac{A_{i0}}{A_0}\frac{V_i}{V_{i0}}$$

where V_i is the amount of physical units produced by the "ith" industry. In other words, an industry's share of activity is represented as the product-base-year share of total industrial GDP and the growth in physical units where available. This measure of activity can be summed across industries and is not subject to changes in prices over time as the growth of an industry's activity is represented by the growth in physical units.

Note that not all industries produce homogeneous products (e.g., transportation equipment manufacturing is a very diverse industry with many different products that do not share a common physical measure). For those industries for which physical data are unavailable, the standard definition of activity share is used, with GDP representing activity:

$$a_i = \frac{A_i}{A}$$

Adjustments for Weather

Since weather can exert a large influence on the intensity of energy use, the "pure" intensity index suffers from the defect that it includes weather effects. This section extends the factorization to include weather adjustments. These adjustments are applicable in the residential and commercial sectors for activities that are related to space heating and cooling.

The weather adjustment takes the form following:

$$\Omega = w\Omega'$$

where "w" is the weather adjustment and Ω' is the weather-adjusted in intensity. For space heating and cooling activities, an estimate of "w" is available directly in the form of a degree-day elasticity. However, for aggregate sectors that span sub-sectors with different weather adjustments or have only some sub-sectors subject to adjustment, the sector's total weather adjustment must be computed implicitly as follows:

$$w = \frac{\sum_i a_i \Omega_i}{\sum_i a_i \Omega'_i}$$

Using this notation, the weather adjustment is incorporated into the "pure" intensity index:

$$\frac{I}{I_0} - 1 = \sum_i b_i \left(\frac{\Omega_i}{\Omega_{i0}} - 1 \right) = \sum_i b_i \left(\frac{w_i \Omega'_i}{w_{i0} \Omega'_{i0}} - 1 \right)$$

Factoring the term in parentheses yields:

$$\frac{I}{I_0} - 1 = \sum_i b_i \left(\frac{w_i}{w_{i0}} - 1 \right) + \sum_i b_i \left(\frac{\Omega'_i}{\Omega'_{i0}} - 1 \right) + \sum_i b_i \left(\frac{w_i}{w_{i0}} - 1 \right) \left(\frac{\Omega'_i}{\Omega'_{i0}} - 1 \right)$$

This expresses the changes in the "pure" intensity index as the sum of the changes in a "pure" weather index, a "pure" weather-adjusted intensity index and a new interaction term. The notation W will be used for the "pure" weather index. I' for the pure weather-adjusted intensity index and λ for the weather-intensity interaction term. The factorization of changes in the total energy index, for those sectors subject to weather adjustment, is now as follows:

$$\frac{E}{E_0} - 1 = \left(\frac{A}{A_0} - 1 \right) + \left(\frac{S}{S_0} - 1 \right) + \left(\frac{W}{W_0} - 1 \right) + \left(\frac{I'}{I'_0} - 1 \right) + \lambda + \delta + \varepsilon$$

The two new indexes can be interpreted in the same way as the other "pure" indexes. That is, the weather index measures what the energy index would have been had all factors but weather adjustment remained at base-period values, and the weather-adjusted index measures what it would have been had all other factors but weather-adjusted intensities remained at base-period values.

Decomposition Applied to the Total Economy

The five sectors comprising energy use for the total economy lack a common activity measure (i.e., activity in the industrial sector is measured by GDP and physical units of output, while activity in the residential sector is measured by floor space). Therefore, the decomposition of the total energy index into a total activity index, total structure index, etc. is problematic. However, the changes in the energy index can be represented as follows:

$$\frac{E}{E_0} - 1 = \sum_i b_i \left(\frac{E_i}{E_{i0}} - 1 \right)$$

where "b_i", as before, denotes the sector's base-period energy share. For each of the four sectors, we have decomposed the changes in their energy indexes as follows:

$$\frac{E_i}{E_{i0}} - 1 = \left(\frac{A_i}{A_{i0}} - 1 \right) + \left(\frac{S_i}{S_{i0}} - 1 \right) + \left(\frac{W_i}{W_{i0}} - 1 \right) + \left(\frac{I'_i}{I'_{i0}} - 1 \right) + \lambda_i + \delta_i + \varepsilon_i$$

so the changes in the total economy energy index can be written this way:

$$\frac{E}{E_0} - 1 = \sum_i b_i \left(\frac{A_i}{A_{i0}} - 1 \right) + \sum_i b_i \left(\frac{S_i}{S_{i0}} - 1 \right) + \sum_i b_i \left(\frac{W_i}{W_{i0}} - 1 \right) + \sum_i b_i \left(\frac{I'_i}{I'_{i0}} - 1 \right) + \sum_i b_i \lambda_i + \sum_i b_i \delta_i + \sum_i b_i \varepsilon_i$$

This formula is used to attribute changes in the total economy energy index to generic activity, structure, weather, weather-adjusted intensity and interaction effects.

3 The OEE Energy Efficiency Index Factorization

The OEE energy efficiency index was developed to provide a single index of secondary energy efficiency, adjusted for structural changes in the economy and weather, for the five sectors that are reviewed in this report. This index is produced using the factorization method described above. The index can be written as follows:

$$OEE = 1 + \left(1 - \sum_j \left(\frac{\left(E_{j0} \big/ E_0 \right) \times \frac{A_j}{A_{j0}}}{\sum_j \left(E_{j0} \big/ E_0 \right) \times \frac{A_j}{A_{j0}}} \times \frac{I'_j}{I'_{j0}} \right) \right)$$

where *OEE* denotes the OEE energy efficiency index, E_{j0} / E_0 represents the individual sectors' base-period energy share, I' represents the pure weather-adjusted intensity and j refers to the "jth" sector of the economy (e.g., residential, industrial). Throughout the analysis in this report, changes in energy efficiency are estimated by changes in energy intensity. The OEE energy efficiency index is, therefore, based on an index of secondary energy intensity which is adjusted for structural changes to the economy and weather for the five sectors. For all five sectors, the efficiency index is the sum of the product of the sectoral activity index, energy intensity index[4] and the base-period energy share, divided by the sum of the products of the sectoral activity indexes and base-period energy shares.

Thus, an increase or decrease in energy efficiency (i.e., greater or lesser levels of activity requiring respectively lower or higher amounts of energy input) will result in a respective increase or a decrease in the index.

Note on Interaction Terms

Earlier in this development, the following identity was introduced:

$$xy - 1 = (x - 1) + (y - 1) + (x - 1)(y - 1)$$

As stated, this identity is useful when studying an index that is the product of two other indexes, since it factors the changes in the product into the changes of the two indexes plus an interaction term. It is this identity on which the quality of our "factorization" depends. When the changes in "x" and "y" are modest, the interaction term can be ignored, and the behaviour of the two component indexes can be focused upon. As an example, the two component indexes can change by 10 percent and the interaction term will be only 1 percent. So, in this case, it is reasonable to ignore the interaction term and say that the product of the two interaction terms has changed by 20 percent, of which 10 percent comes from "x" and the other 10 percent comes from "y".

The direction of the error in approximation depends on the direction of change in the component indexes. If the component indexes both increase or both decrease, the interaction term is always positive, so the sum of the changes in the component indexes underestimates the total change. If the component indexes differ in the direction of their changes, then the interaction term is always negative, so the sum of the changes overestimates the total change.

The interaction term, ε, can be comfortably ignored as it is the product of the changes in the total activity index and the average intensity index – both of which are expected to change only modestly. However, δ and λ cannot be ignored, as they are both the sum of interaction terms across all sub-sectors. Even if is believed that sub-sector interaction

4 Changes in energy intensity are used to approximate changes in energy efficiency.

contributions are small, the fact that these are added up must not be forgotten. The interaction term, δ, deserves special consideration because one of the component indexes is the activity share index. Thus, caution must be used in looking at components of δ when it is expected that a sub-sector has gained considerable activity share. A sub-sector that changes its activity share from 5 percent to 10 percent (or 1 percent to 2 percent) has an activity-share-index change of 100 percent. This condition is moderated somewhat by the fact that the contribution of the sub-sector to δ is weighted by its base-period energy share. That is, its contribution to the total interaction term will be large only if it has a large base-period energy share.

Decomposition Applied to End-Use Sectors

Total secondary energy consumed in the economy is the sum of the secondary energy consumed by each of the end-use sectors, as defined by Natural Resources Canada (see Appendix D):

1) industrial
2) transportation
3) residential
4) commercial (including public administration)
5) agriculture

The factorization methodology provides a basis for distinguishing between activity, structure and intensity factors, but the activity measure appropriate for any particular sector may not be applicable to another. The following activity measures are used for each sector:

Industrial – GDP and physical units originating from the sector
Transportation – passenger-kilometres and freight tonne-kilometres
Residential – number of households and the floor space of houses
Commercial (including public administration) – floor space
Agriculture – GDP

Industrial Sector

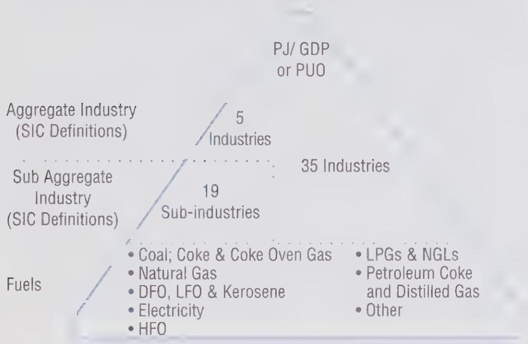
The industrial decomposition is based on energy consumption per unit of industrial output (GDP) or per unit of physical production for 40 sub-sectors in the mining (3), construction (1), forestry (1) and manufacturing (35) sectors.

Secondary end-use energy information is compiled by Natural Resources Canada for use in its industrial sector energy end-use models. The data are similar to information that Statistics Canada publishes in the *Quarterly Report on Energy Supply-Demand in Canada* (Cat. No. 57-003), with modifications to account for waste fuels consumption in the cement industry, hog fuel and pulping liquor consumption and producer's consumption of refined petroleum products, in the mining and petroleum refining sectors, as well as some historical revisions mainly pertaining to natural gas and butane consumption by the chemical, mining and other manufacturing industries.

Industrial output data for the 40 sub-sectors are aggregations of GDP by industry (at 1986 prices) or physical units of production (when available). GDP data are produced by Statistics Canada, published in *Gross Domestic Product by Industry* (Cat. No. 15-001) and physical units of output data are reported by CIEEDAC in its publication, *Development of Energy Intensity Indicators for Canadian Industry 1990 to 1998*. Statistics Canada and CIEEDAC use the Standard Industrial Classification (SIC) system to identify industries. It should be noted that industry GDP and physical units of output disaggregated by fuel type are not available. Instead, estimates were constructed using shares of output energy demand.

As shown on the indicator pyramid (Figure C.1), the factorization of energy use for the industrial sector involves four levels. Level 1 (at the bottom) defines the sectoral influences at the most detailed level by fuel type. Levels 2 and 3 capture the influence of shifting industrial composition (shift in fuel or sub-sectors). Aggregating over the products of these factors yields the fourth level, the change in aggregate industrial secondary end-use attributable to each of the three components (activity, structure and intensity) in petajoules per unit of output.

Figure C.1: Industrial Sector Indicator Pyramid



PUO: Physical Units of Output
DFO: Diesel Fuel Oil
LFO: Light Fuel Oil
HFO: Heavy Fuel Oil
LPGs: Liquefied Petroleum Gases
NGLs: Natural Gas Liquids
Other includes: Steam, Hog Fuel and Pulping Liquor
Note: As there are 54 industries and sub-industries, they are not listed here.

Transportation Sector

The structure for analysing transportation is based on a division of transportation activity into two parts: passenger and freight. Due to its small portion of overall energy use and a lack of available data, off-road transportation is not included in the OEE's factorization analysis.

Passenger Transport

The passenger transport decomposition is based on energy consumption per passenger-kilometre for nine modal subaggregates in the road (4), bus (3), rail (1) and air (1) sub-sectors.

Secondary end-use energy information is compiled by Natural Resources Canada for use in its transportation sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (Cat. No. 57-003), with modifications to account for all use of motor gasoline, commercial and other institutional use of diesel fuel oil and aviation fuel, public administration use of diesel fuel oil and aviation fuels and some historical revisions.

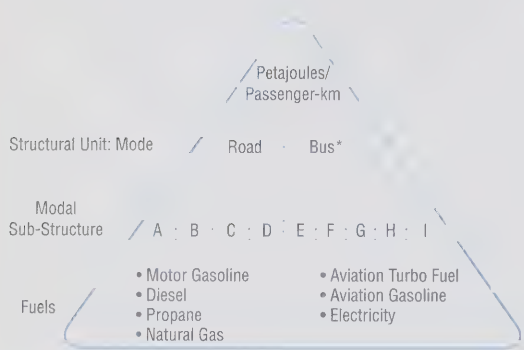
Passenger-kilometre data are drawn from a number of sources:

- Road data are based on the change in the average population per vehicle (which was benchmarked in 1990) to the average number of passengers per car (which was reported in the *Royal Commission on Passenger Transportation*, Volume 2), multiplied by the distance that cars travel. The same benchmark (average number of passengers per car) is used for both large and small cars. Trucks are defined as light trucks, excluding those used for commercial purposes.
- Bus data are defined as the product of the total distance that buses travelled and average bus-occupancy levels. Average bus occupancies are benchmarked in 1990 to the bus seat capacity and occupancy ratios from the *Royal Commission on Passenger Transportation*, Volume 2. Variations in bus-occupancy levels are approximated, based on the index of the ratio of total passengers to the total distance travelled and an index of average trip distance. Total passengers and distance travelled data series are drawn from Statistics Canada's *Passenger Bus and Urban Transit Statistics* (Cat. No. 53-215), while the data on average trip distances comes from the Commission de Transport de la Communauté de Montréal.

- Rail data are reported in Statistics Canada's *Rail in Canada* (Cat. No. 52-216).
- Air data are drawn from Natural Resources Canada's database, which is based on Statistics Canada's airline traffic statistics.

As shown on the indicator pyramid (Figure C.2), the factorization of energy use for the passenger transport sector involves four levels. In this instance, Levels 2 and 3 capture the influence of shifting modal structure.

Figure C.2: Passenger Transport Indicator Pyramid



*Not decomposed in aggregate

Modal Sub-Structure

A: Motorcycles & Mopeds	F: Intercity
B: Large Cars	G: Urban Transit
C: Small Cars	H: Rail
D: Light-Duty Trucks	I: Air
E: School	

Freight Transport

The freight transport decomposition is based on energy consumption per freight tonne/kilometre for five modal subaggregates in the truck (3), rail (1) and marine (1) sub-sectors.

Secondary end-use energy information is compiled by Natural Resources Canada for use in the transportation sector energy end-use model. The data are similar to information that Statistics Canada publishes in the *Quarterly Report on Energy Supply-Demand in Canada* (Cat. No. 57-003), with modifications to account for all uses of motor gasoline, commercial and other institutional use of diesel fuel oil, public administration use of diesel fuel oil and some historical revisions. End-use energy demand by medium-duty and large trucks was scaled down by the amounts reported for bus passenger transport.

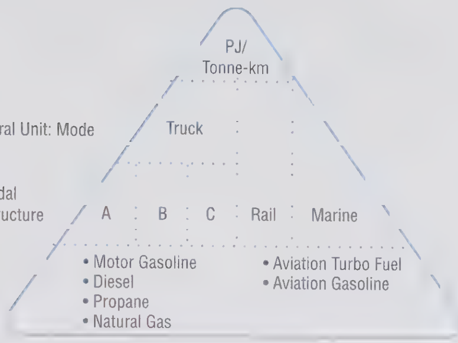
Freight tonne-kilometre data are drawn from a number of sources:

- Truck data were drawn from Statistics Canada's *Trucking in Canada* (Cat. No. 53-222) and Transport Canada's *Transportation in Canada* (Annual Report) for the heavy truck categories. A fixed tonnage of 500 kilograms and 1500 kilograms per kilometres have been assigned to the light- and medium-duty trucks categories, as they pertain mainly to service trucking[5] rather than freight. Light trucks are defined as excluding those used for personal use. Tonne-kilometres were attributed by fuel type based on input fuel consumption.
- Rail data were drawn from Statistics Canada's *Rail in Canada* (Cat. No. 52-216).
- Marine data were drawn from Transport Canada, Marine and Surface Statistics and Forecast, Economic Analysis, Policy and Coordination Group.

As shown on the indicator pyramid (Figure C.3), the factorization of energy use for the freight transport sector involves four levels. Once again, levels 2 and 3 capture the influence of shifting modal structure.

5 service trucking includes e.g : firetruck ....

Figure C.3: Freight Transport Indicator Pyramid



Modal Sub-Structure
A: Less than 3 855 kg
B: 3 856 to 14 969 kg
C: Greater than 14 970 kg

Residential Sector

The structure for analysing residential energy use is based on a division of residential activity in two parts: household services and floor space services. The activity indicator used for household services is the number of households, while area is used for floor space services. When the analysis is done at the sector level, an activity index based on households and floor area is used.

Secondary end-use energy information is produced by Natural Resources Canada for use in the residential sector energy end-use model. The data are similar to information that Statistics Canada publishes in the *Quarterly Report on Energy Supply-Demand in Canada* (Cat. No. 57-003), with some historical revisions.

Floor Space Services

The floor space services decomposition is based on energy consumption per square metre for three end-uses: space heating, space cooling and lighting.

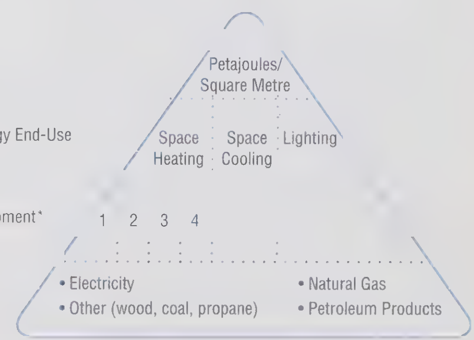
The floor space data are produced by NRCan using two sources:

- The average area of houses per province, house type, and period of construction is produced by NRCan using results from the 1993 and 1997 *Survey of Household Energy Use.*
- Household data are also produced by NRCan and are based on household and housing stock data produced by Statistics Canada, Household Surveys Division and Investment and Capital Stock Division.

Those two sources of information are then combined to produce an estimate of the total floor area of houses in Canada.

As shown on the indicator pyramid (Figure C.4), the factorization of energy use for the residential sector involves four levels. For this sector, levels 2 and 3 measure the impact of shifting choices in appliances.

Figure C.4: Residential Sector Floor Space Services Indicator Pyramid

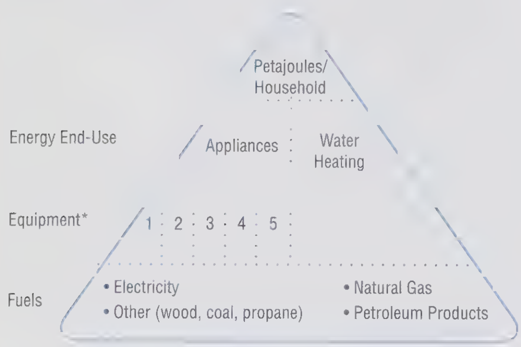


*Equipment examples include:
Space heating – normal, mid- and high-efficiency furnaces, electric baseboard heaters, heat pumps, coal, dual wood and propane furnace system
Space cooling – room air conditioners and central air conditioners

Household Services

The household services decomposition is based on energy consumption per household for two end-uses: appliances and water heating. The household data used for this portion of the analysis are the same as those that are used to derive the floor area data. They are produced by NRCan and are based on household and housing stock data produced by Statistics Canada, Household Surveys Division and Investment and Capital Stock Division.

Figure C.5: Residential Sector Household Services Indicator Pyramid



*Equipment examples include:
Appliances – refrigerator, freezer, clothes washer, electric and gas dryers, electric and gas ranges, dishwasher.

Commercial Sector

The commercial decomposition is based on energy consumption per square metre of floor space for nine building types.

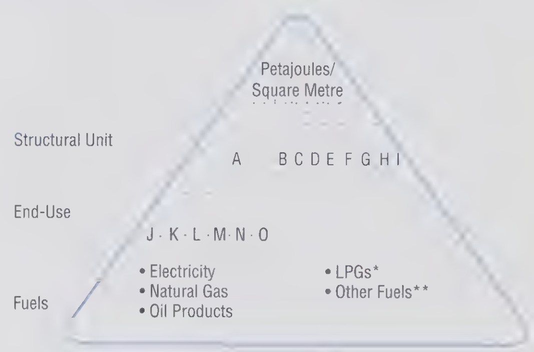
Secondary end-use energy information is compiled by Natural Resources Canada for use in its commercial sector energy end-use model.

The data are similar to information that Statistics Canada publishes in the *Quarterly Report on Energy Supply-Demand in Canada* (Cat. No. 57-003), with commercial and institutional motive fuel use reallocated to the transportation sector. Electricity for street lighting, as published by Statistics Canada *Electric Power Statistics* (Cat. No. 57-202), was removed from the factorization.

Floor space data are produced by Informetrica Limited for Natural Resources Canada and are based on investment and capital stock data produced by Statistics Canada, Investment and Capital Stock Division.

As shown on the indicator pyramid (Figure C.6), the factorization of energy use for the commercial sector involves four levels. For this sector, level 2 captures appliance-mix effects, while level 3 captures the influence of building types.

Figure C.6: Commercial Sector Indicator Pyramid



Structural Units

A: Schools
B: Health
C: Religious
D: Other Institutions
E: Office
F: Retail
G: Accomodation and Restaurant
H: Recreation
I: Wholesale (warehouse)

End-Uses

J: Space Heating
K: Cooling
L: Ventilation
M: Equipment
N: Lighting
O: Water Heating

* Liquefied Petroleum Gases
** Coal, steam

Reconciliation of Data on Energy Use Found in This Report

with Statistics Canada's *Quarterly Report on Energy Supply-Demand in Canada* Data – 1998

Introduction

The bulk of the energy use data that are presented in this report are taken from Statistics Canada's *Quarterly Report on Energy Supply-Demand in Canada* (QRESD). Several sectoral re-allocations and data improvements that were made in previous reports were no longer required in this report since Natural Resources Canada initiated and funded a major review of QRESD for 1990–1998. However, for the purpose of the analysis undertaken in this study, some modifications to the original Statistics Canada data were still required and are documented in Table D.1.

The following describes modifications to QRESD sector definitions in each end-use sector for the purpose of this report.

Residential Sector

One modification was made to the QRESD definition of the residential sector: the addition of fuel wood use. The inclusion of fuel wood use is a net addition to residential energy demand as reported in the QRESD. Residential fuel wood use is estimated using Natural Resources Canada's Residential End-Use Model.

Commercial Sector

One modification was made to the QRESD definition of the commercial sector: the re-allocation of commercial and public administration motive fuels to the transportation sector in order to include only stationary energy use in the commercial sector. All of the data required for this re-allocation are found in the QRESD and described in Table D.1.

In addition, although it does not affect total commercial electricity demand, street lighting electricity consumption is now identified separately as reported by Statistics Canada's *Electric Power Statistics* (Cat. No. 57–202).

Industrial Sector

Three modifications were made to the QRESD definition of the industrial sector: the reallocation of producer consumption by the petroleum refining and mining industries to the industrial sector, the addition of solid wood waste and spent pulping liquor and the addition of waste fuels used in the cement industry.

The first re-allocation relates to producer consumption by the petroleum refining and mining industries. Statistics Canada classifies the use of non-purchased petroleum products by the petroleum refining and mining industries as producer consumption. In this report, this energy use has been re-allocated to the industrial sector (petroleum refining industry) as it is an end-use consumption.

Data on consumption of solid wood waste and spent pulping liquor is included in a supplementary table in the QRESD but not in the QRESD's energy supply-demand balance. For the purpose of this report, the energy demand of the industrial sector is modified to include spent pulping liquor and wood waste consumption.

Waste fuels used in the cement industry are not included in the QRESD's energy supply-demand balance. In this report, the energy demand of the industrial sector includes waste fuels as reported in CIEEDAC's publication *Development of Energy Intensity Indicators for Canadian Industry, 1990 to 1998.*

Transportation Sector

Two modifications were made to the QRESD definition of the transportation sector: the re-allocation of commercial motive fuels from the commercial and public administration sector and the re-allocation of pipeline fuel use to producer consumption.

Commercial and public administration motive fuels have been re-allocated from the commercial sector to the transportation sector to include only stationary energy use in the commercial sector.

The re-allocation of pipeline fuel use to producer consumption is done in order to include only vehicle energy use in the transportation sector. Since pipeline fuel is fuel that is used in the distribution of energy to end-use markets, we have re-allocated it to producer consumption and do not consider it end-use consumption.

Agricultural Sector

No modification.

Table D.1: Reconciliation of Data on Energy Use Found in This Report with Statistics Canada's *Quarterly Report on Energy Supply Demand in Canada* Data (CANSIM) – 1998

Sector	(CANSIM) QRESD data	Fuel Wood	Commercial & Public Admin. Diesel	Commercial & Public Admin. Aviation Fuels	Commercial & Public Admin. Motor Gasoline	Pipeline Fuels	Solid Wood Waste & Pulping Liquor	Waste Fuels Used in Cement Industry	Re-allocation of Producer Consumption by Refining	Energy Efficiency Trends Data
Residential	1180	107								1288
Commercial	1142		(109)	(30)	(59)					944
Industrial	2156						474	6	391	3026
Transportation	2244		109	30	59	(261)				2182
Agriculture	225									225
Final Demand	6948	107	0	0	0	(261)	474		391	7664
Non-Energy	777									777
Producer Consumption	1095					261			(391)	965
Net Supply	8820	107	0	0	0	0	474		0	9406
Conversion Losses*	1469									1469
Total Primary	10288	107	0	0	0	0	474	6	0	10875

Notes on Sources of Energy Use Data for Five End-Use Sectors:

Residential: Base data taken from revised QRESD (Table 1B, line 44) plus fuel wood use (estimated from NRCan's Residential End-use Model).

Agriculture: Base data taken from revised QRESD (Table 1B, line 43).

Commercial: Base data taken from revised QRESD (line 45 plus line 46) less commercial and public administration motor gasoline (Table 1D, motor gasoline column, line 45 plus line 46) less commercial and public administration diesel (Table 1D, diesel column, line 45 plus line 46) less commercial and public administration aviation gasoline (Table 1D, aviation gasoline column, line 45 plus line 46) less commercial and public administration aviation turbo fuel (Table 1D, aviation turbo fuel column, line 45 plus line 46).

Transportation: Base data taken from revised QRESD (Table 1B, line 42) less pipeline fuels (Table 1B, natural gas plus electricity plus petroleum products columns, line 39) plus commercial and public administration motor gasoline (Table 1D, motor gasoline column, line 45 plus line 46) plus commercial and public administration diesel (Table 1D, diesel column, line 45 plus line 46) plus commercial and public administration aviation gasoline (Table 1D, aviation gasoline column, line 45 plus line 46) plus commercial and public administration aviation turbo fuel (Table 1D, aviation turbo fuel column, line 45 plus line 46).

Industrial: Base data taken from revised QRESD (Table 1B, line 31) plus solid wood waste and pulping liquor (Table 19) plus producer consumption by refinery industry of still gas, diesel, heavy fuel oil, light fuel oil, kerosene, petroleum coke and refinery LPG (Table 1D, still gas, diesel, heavy fuel oil, light fuel oil, kerosene, petroleum coke and refinery LPG columns, line 16).

* Electricity conversion rates: Hydro-electricity converted at rate of 3.6 megajoules per kilowatt-hour; nuclear electricity converted at rate of 11.564 megajoules per kilowatt-hour.

Reconciliation of Definition of Estimated Greenhouse Gas Emissions Found in This Report

with Environment Canada's *Canada's Greenhouse Gas Inventory: 1997 Emissions and Removals with Trends*

1. Introduction

The data on greenhouse gases, particularly the data on carbon dioxide emissions, presented in this report are estimated using emissions factors developed by Environment Canada (EC). The emissions estimates provided herein mirror the sectoral definitions used to calculate estimates presented in *Canada's Greenhouse Gas Inventory: 1997 Emissions and Removal with Trends* (CGGI-1997), since both Natural Resources Canada (NRCan) and EC use the energy demand data from Statistics Canada's *Quarterly Report on Energy Supply Demand* (QRESD) as a base. However, the two organizations use different sectoral mappings.

EC prepares its emissions inventory according to the specifications of the Intergovernmental Panel on Climate Change. NRCan has developed a mapping that is most suited to energy end-use analysis. The objective of this appendix is to help readers understand the similarities and differences between CGGI-1997 and NRCan sectoral emissions estimates for the five end-use sectors which are covered in this report. The comparison is presented for the year 1998 for illustrative purposes.

2. Residential Sector

There are differences between NRCan and CGGI-1997 residential emissions definitions. First, NRCan residential emissions include end-use electricity-related emissions, which are reported under power generation in CGGI-1997.

Second, there is a difference between the wood energy use presented in the report and CGGI–1997 (EC's estimate being larger than NRCan's). As a result, the wood use related GHG emissions presented here are smaller than those in CGGI–1997.

3. Agriculture Sector

For the agriculture sector, CGGI-1997 reclassifies all farm diesel and motor gasoline in the transport sector, while NRCan leaves this consumption in the agricultural sector, as is done in the QRESD.

NRCan agricultural emissions also include end-use electricity-related emissions, which are reported under power generation in CGGI-1997.

4. Commercial Sector

There is only one difference between the NRCan and CGGI-1997 definitions of the commercial emissions.

NRCan commercial emissions include end-use electricity-related emissions, which are reported under power generation in CGGI-1997.

5. Industrial Sector

For the industrial sector, there are many differences between the sectoral definitions as described in CGGI-1997 in this report.

First, there is a reallocation in CGGI-1997 of industrial diesel fuel use from the industrial sector to the transportation sector.

Second, in this report there is a reallocation of producer consumption of petroleum products by the petroleum refining and mining industry from the producer consumption sector to petroleum refining and mining within the industrial sector. In CGGI-1997, this consumption is reported under fossil fuels.

Third, there is a reallocation in CGGI-1997 of industrial coke use from energy use in the industrial sector to non-energy use in industrial processes.

Fourth, NRCan industrial emissions include end-use electricity-related emissions. These are reported under power generation in CGGI-1997.

Fifth, producers' consumption of non-fossil fuels is included in the fossil fuel categories in CGGI-1997. NRCan does not report this consumption. CGGI-1997 also reallocates estimates of emissions from upstream oil and gas flaring to the fugitive emissions from the fossil fuel sector.

6. Transportation Sector

Differences to the boundary of the transportation sector between NRCan and CGGI-1997 are related to reallocation or exclusion of QRESD data in CGGI-1997 from its inventory, and allocation by NRCan of end-use electricity-related emissions to the end-use sectors.

First, there is the reallocation to the transportation sector of industrial diesel, and farm diesel and motor gasoline.

Second, there is the exclusion from EC's inventory of emissions resulting from the use of energy in the foreign marine and foreign aviation sub-sectors.

Third, NRCan transportation emissions include end-use electricity-related emissions, which are reported under power generation in CGGI-1997.

Greenhouse Gas Emissions Trends Analysis

The analysis of greenhouse gas emissions (GHG) from the use of energy, presented in this report, is summarized by the following set of equations:

First, $$GHG_{sec} = GHG_{res} + GHG_{com} + GHG_{ind} + GHG_{tran} + GHG_{agr} \quad (1)$$

where
GHG_{sec}: greenhouse gas emissions from secondary energy use
GHG_{res}: greenhouse gas emissions from residential energy use
GHG_{com}: greenhouse gas emissions from commercial energy use
GHG_{ind}: greenhouse gas emissions from industrial energy use
GHG_{tran}: greenhouse gas emissions from transportation energy use
GHG_{agr}: greenhouse gas emissions from agriculture energy use

The elements of equation 1 were presented in Chapter 2, which provides an overview of trends in GHG emissions and energy use at the aggregate secondary level.

In each energy-consuming sector, energy-related GHG emissions are the product of energy use and the GHG intensity of this energy use. This is written as follows:

$$GHG = E \times (GHG/E) \quad (2)$$

where
GHG: greenhouse gas emissions
E: energy use
GHG/E: greenhouse gas intensity of energy use

For this report, the greenhouse gas intensity of energy is based on three greenhouse gases: carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). Using global warming potentials, both N_2O and CH_4 are expressed as CO_2 equivalents.

Table F.1

Greenhouse Gas	Global Warming Potential - CO_2 equivalents
CO_2	1
N_2O	310
CH_4	21

The greenhouse gas intensity of energy use can be expanded and represented by the following equation:

$$GHG/E = CO_2/E + (N_2O/E \times 310) + (CH_4/E \times 21) \quad (3)$$

where
CO_2/E: carbon dioxide intensity of energy use
N_2O/E: nitrous oxide intensity of energy use
CH_4/E: methane intensity of energy use

For the purposes of this report, the change (expressed as Δ in the equation below) in GHG emissions is approximated by the sum of growth in energy use and GHG intensity:

$$\Delta GHG \approx \Delta E + \Delta (GHG/E) \qquad (4)$$

This only approximates the change in GHG emissions, as the actual change in GHG emissions is equal to the right-hand side of equation 4 and the product of the growth in E and GHG, that is

$$\Delta GHG = \Delta E + \Delta (GHG/E) + (\Delta E \times \Delta GHG). \qquad (5)$$

The analysis of emissions presented in Chapters 3 to 7 elaborates on the principal factors underlying growth in both energy use and GHG intensity of energy use for the five end-use sectors.

Glossary of Terms

The glossary is divided into six sections: General, Residential Sector, Commercial Sector, Industrial Sector, Transportation Sector and Agricultural Sector. The General section includes general terminology as well as terminology common to more than one sector.

General

Activity: Term used to characterize major drivers of energy use in a sector (e.g., number of households in the residential sector).

Calibration process: Process by which deviations between disaggregated and aggregated data are determined and rectified.

Canada's National Action Program on Climate Change (NAPCC): Sets strategic directions in pursuit of Canada's commitment to stabilize greenhouse gas emissions at 1990 levels by the year 2000 and provides guidance for actions beyond the year 2000. The NAPCC pursues sectoral and broad-based opportunities through the development of appropriate actions and measures by private and public jurisdictions, reviews progress, and makes adjustments as required.

Carbon dioxide: A compound of carbon and oxygen formed whenever carbon is burned. Chemical formula: CO_2. Carbon dioxide is a colourless gas that absorbs infrared radiation mostly at wavelengths between 12 and 18 microns; it behaves as a one-way filter allowing incoming, visible light to pass through in one direction while preventing outgoing infrared radiation from passing in the opposite direction. The one-way filtering effect of carbon dioxide causes an excess of the infrared radiation to be trapped in the atmosphere; thus, it acts as a greenhouse and has the potential to increase the surface temperature of the Earth.

Climate change: A change attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which, in addition to natural climate variability, is observed over comparable time periods.

Compressor: A compressor is used in refrigeration and cooling systems to compress vaporized refrigerant.

Cooling Degree-Days: A measure of how hot a location was over a period of time relative to a base temperature. In this report, the base temperature is 18˚C; the period of time is one year. The cooling degree-days for a single day is the difference between that day's average temperature and 18˚C, if the daily average exceeds the base temperature. It is zero, if the daily average is less than or equal to the base temperature. The cooling degree-days for a longer period of time is the sum of the daily cooling degree-days from the days in the period.

End-use: Any specific activity that requires energy (e.g., refrigeration, space heating, water heating, manufacturing process, feedstocks).

Energy efficiency indicators: Indicators of how efficiently energy is used.

Energy intensity: The amount of energy use per unit of activity (examples of activity measures in this report are households, floor space, passenger-kilometres, tonne-kilometres, physical units of production or constant dollar value of gross domestic product by industry).

Energy source: Any substance that supplies heat or power (e.g., petroleum, natural gas, coal, renewable energy, and electricity, including the use of a fuel as a non-energy feedstock).

Factorization method: A method used to decompose changes in the total energy used in a sector over a certain period of time, into changes in the overall demand for that sector's output, changes in the structural composition of the

sector, and changes in the energy intensity of the individual sub-sectors contributing to the sector's output. The factorization method used in this report is the Laspeyre index.

Fossil fuel: Any naturally occurring organic fuel, such as petroleum, coal and natural gas.

Gigajoule: One gigajoule equals 1 x 10^9 joules. A joule is the international unit of energy – the energy produced by a power of one watt flowing for one second. There are 3.6 million joules in one kilowatt-hour (see Kilowatt-hour).

Global warming: See Greenhouse gas.

Greenhouse gas: A greenhouse gas absorbs and radiates heat in the lower atmosphere that otherwise would be lost in space. The greenhouse effect is essential for life on this planet since it keeps average global temperatures high enough to support plant and animal growth. The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs) and nitrous oxide (N_2O). By far the most abundant greenhouse gas is CO_2, accounting for 70 percent of the greenhouse effect (see Carbon Dioxide).

Greenhouse gas intensity of energy: The amount of greenhouse gas emissions per unit of energy.

Gross Domestic Product (GDP): The total value of goods and services produced by the nation's economy before deduction of depreciation charges and other allowances for capital consumption, labour and property located in Canada. It includes the total output of goods and services by private consumers and government, gross private domestic capital investment, and net foreign trade. GDP figures are reported in real 1986 dollars.

Gross output: The total value of goods and services produced by an industry, a sum of the industry's shipments plus the change in value due to labour and capital investment.

Heating Degree-Days: A measure of how cold a location was over a period of time relative to a base temperature. In this report, the base temperature is 18˚C; the period of time is one year. The heating degree-days for a single day is the difference between that day's average temperature and 18˚C, if the daily average is below the base temperature. It is zero, if the daily average exceeds or equals the base temperature. The heating degree-days for a longer period is the sum of daily heating degree-days for days in that period.

Hydroelectric generation: Electricity produced by an electric generator driven by a hydraulic turbine.

Interaction effect: In the factorization method, this is a weighted average of the change in intensity and structure variables.

Kilowatt-hour (kWh): The commercial unit of electric energy equivalent to 1000 watt hours. A kilowatt-hour can best be visualized as the amount of electricity consumed by ten 100-watt light bulbs burning for an hour. One kilowatt-hour is equal to 3.6 million joules (see Watt).

Megajoule: One megajoule equals 1 x 10^6 joules (see Gigajoule).

Megawatt-hour (MWh): One megawatt-hour equals 1 x 10^6 watt hours (see Kilowatt-hour).

Motive power: Power provided by electric motors for driving fans, pumps, elevators or other types of equipment.

Penetration rate: The rate at which a technology infiltrates the stock of buildings (e.g., number of refrigerators per household at a specified time).

Per capita: Per person.

Petajoule: One petajoule equals 1 x 10^{15} joules (see Gigajoule).

Petroleum: A naturally occurring mixture of predominantly hydrocarbons in the gaseous, liquid or solid phase.

Primary energy use: Represents the total requirements for all uses of energy, including energy used by the final consumer (see Secondary energy use), non-energy uses, intermediate uses of energy, energy in transforming one energy form to another (e.g., coal to electricity), and energy used by suppliers in providing energy to the market (e.g., pipeline fuel).

Production of electricity: The amount of electric energy expressed in kilowatt-hours produced in a year. The determination of electric energy production takes into account various factors, such as the type of service for which generating units were designed (e.g., peaking or base load), the availability of fuels, the cost of fuels, stream flows and reservoir water levels, and environmental constraints.

Real disposable income per household: Money, in constant dollars, available to individuals per household for spending and saving after taxes and social insurance premiums, such as employment insurance and Canada Pension Plan premiums, have been deducted. Personal disposable income is the principal source of savings and spending in the economy.

Retrofit: Improvement in the energy efficiency of existing energy-using equipment or the thermal characteristics of an existing building.

Secondary energy use: Energy used by final consumers for residential, agricultural, commercial, industrial and transportation purposes.

Sector: The broadest category for which energy consumption and intensity are considered within the Canadian economy (e.g., residential, agriculture, commercial, industrial and transportation).

Space cooling: Conditioning of room air for human comfort by a refrigeration unit (e.g., air conditioner or heat pump) or by circulating chilled water through a central-cooling or district-cooling system.

Space heating: The use of mechanical equipment to heat all or part of a building. Includes both the principal space-heating and supplementary space-heating equipment.

Structural change: As it affects energy efficiency, structural change is a change in the shares of activity accounted for by the energy-consuming sub-sectors within a sector. An example of structural change is a change in industry mix in the industrial sector.

Ventilation: The circulation of air through a building to deliver fresh air to occupants.

Vintage: The year of origin or age since the construction of a unit of capital stock (e.g., a building, a car).

Water heating: The use of energy to heat water for hot running water, as well as the use of energy to heat water on stoves and in auxiliary water-heating equipment for bathing, cleaning and other non-cooking applications. An automatically controlled, thermally insulated vessel designed for heating water and storing heated water.

Watt (W): A measure of power, for example a 40-watt light bulb uses 40 watts of electricity (see Kilowatt-hour).

Weather-Adjusted Energy Intensity: A measurement of energy intensity that excludes the impact of weather.

Residential Sector

Annual Fuel Utilization Efficiency (AFUE): This is an energy rating (stated as a percentage, such as 90 percent) that indicates how efficiently a new furnace or boiler will heat a home. The higher the number, the more efficient the heating equipment.

Apartment: This type of dwelling includes dwelling units in apartment blocks or apartment hotels; flats in duplexes or triplexes (i.e., where the division between dwelling units is horizontal); suites in structurally converted houses; living

quarters located above or in the rear of stores, restaurants, garages or other business premises; janitors' quarters in schools, churches, warehouses, etc.; and private quarters for employees in hospitals or other types of institutions.

Appliances: Energy-consuming equipment used in the home for purposes other than air conditioning or centralized water heating. Includes cooking appliances (gas stoves, gas ovens, electric stoves, electric ovens, microwave ovens, and propane or gas grills); cooling appliances (evaporative coolers, attic fans, window or ceiling fans, portable or table fans); and refrigerators, freezers, clothes washers, electric dishwashers, electric clothes dryers, outdoor gas lights, electric dehumidifiers, personal computers, electric pumps for well water, black-and-white televisions, colour televisions, water bed heaters, swimming pools, swimming pool heaters, hot tubs, and spas.

Dwelling: A dwelling is defined as a structurally separate set of living premises with a private entrance from outside the building or from a common hallway or stairway inside. A private dwelling is one in which one person, a family or other small group of individuals may reside, such as a single house, apartment, etc.

Floor area (space): The area enclosed by exterior walls of a building, excluding parking areas, basements or other floors below ground level. It is measured in square metres.

Furnace: Space-heating equipment consisting of an enclosed chamber where fuel is burned or electrical resistance is used to heat air directly, without using steam or hot water. The warm air is for heating and is distributed throughout the house, typically by air ducts.

Heated living area: The area within a dwelling that is space heated.

Household: A person or a group of persons occupying one dwelling unit is defined as a household. The number of households will, therefore, be equal to the number of occupied dwellings. The person or persons occupying a private dwelling form a private household.

Household size: The number of persons per household.

Mobile home: A moveable dwelling designed and constructed to be transported (by road) on its own chassis to a site and placed on a temporary foundation such as blocks, posts or a prepared pad. It should be capable of being moved to a new location.

Single-attached dwelling: Each half of a semi-detached (double) house and each section of a row or terrace is defined as a single-attached dwelling. A single dwelling attached to a non-residential structure also belongs to this category.

Single-detached dwelling: This type of dwelling is commonly called a single house (i.e., a house containing one dwelling unit and completely separated on all sides from any other building or structure).

Thermal characteristics: Characteristics of the building envelope in terms of its energy requirements for space heating. The building envelope is the collection of components that separate heated space from unheated space such as walls, roof, floors, windows, doors, insulation materials, etc.

Commercial Sector

Ballasts: A ballast is a device used with a fluorescent-type lamp to provide the necessary starting and operating electric conditions.

Boiler: A pressurized system in which water is vaporized to steam by heat transfer from fuel combustion. Steam thus generated may be used directly as a heating medium or converted to mechanical energy.

Floor area (space): The area enclosed by exterior walls of a building, including parking areas, basements, or other floors below ground level. It is measured in square metres.

Flue gas condensation: The liquids that are formed when exhaust gas condenses on surface in the exhaust stream (ducts, chimneys, etc.).

Liquefied petroleum products (LPG): Propane and butane compose the secondary LPG use. These two fuels are liquefied gases extracted from natural gas and refined petroleum products at the process plant.

Occupancy rate: The number of occupants per square metre of floor area.

Plug load: The electricity demand from all equipment that is plugged into electrical outlets in the buildings, principally office equipment. This means it is the electricity demand other than from space conditioning, ventilation, water heating, and permanent lighting.

Industrial Sector

Auxiliary equipment: Devices that supply energy services to the major process technologies during their operation and that are common to most industries. Auxiliary equipment falls into five categories: steam generation, lighting, heating, ventilation and air conditioning and electric motors including pumps, fans, compressors and conveyors.

Bitumen: Very heavy crude oil or tar consisting of a naturally occurring viscous mixture, mainly of hydrocarbons heavier than pentane that may contain sulphur compounds and other minerals and that, in its natural viscous state is not recoverable at a commercial rate through a well.

Building board: Compressed paper products used as sheeting, backing for furniture, tack boards, etc. It may be used as structural material in construction.

Capacity-utilization rate: The ratio of industrial production to capacity (sustainable practical capacity (i.e., the greatest level of output a plant can maintain within a realistic work schedule).

Coke: A hard, porous product made from baking bituminous coal in ovens at high temperatures.

Coke oven gas: Complex gas (containing hydrogen, methane, light oil, ammonia, pitch, tar and other minerals) released during coke production.

Inorganic chemicals industry: Sub-sector of the chemicals industry represented by SIC 3711. Examples of chemical commodities produced by this sector include caustic soda, sodium chlorate, oxygen, chlorine and sulphuric acid.

Oilsand upgraders: The facility at which bitumen, extracted from the oil sands, is converted to synthetic crude oil.

Organic chemicals industry: Sub-sector of the chemicals industry represented by SIC 3712. Examples of chemical commodities produced by this sector include ethylene, methyl alcohol, benzene, toluene and xylene.

Paperboard: Stiff paper product primarily used to make cartons and containers (cereal boxes, cracker boxes, etc.). It may be layered and used to make book covers and even furniture.

Spent pulping liquor: A substance primarily made up of lignin, other wood constituents, and chemicals that are by-products of the manufacture of chemical pulp. It can be burned in a boiler to produce steam or electricity through thermal generation.

Standard Industrial Classification (SIC): A classification system that categorizes establishments into groups with similar economic activities.

Waste fuels: A name applied to any number of energy sources outside of conventional fuels. It can include materials such as tires, municipal waste and landfill offgases.

Wood wastes: Fuel consisting of bark, shavings, sawdust and low-grade lumber and lumber rejects from the operation of pulp mills, sawmills and plywood mills.

Transportation Sector

Gross vehicle weight: The weight of the empty vehicle plus the maximum anticipated load weight.

Large cars: Cars weighing more than or equal to 1 182 kilograms. (2 601 lb.).

Large trucks: Trucks with a gross vehicle weight of more than or equal to 14 970 kilograms. (30 001 lb.)

Light-duty trucks: Trucks up to 3 855 kilograms (8500 lb.) of gross vehicle weight.

Light vehicles: Cars, motorcycles, and light trucks, including vans.

Medium-duty trucks: Trucks with a gross weight ranging from 3 856 to 14 969 kilograms. (8501 lb. to 33 000 lb.)

Passenger-kilometre: The transport of one passenger over a distance of one kilometre.

Small cars: Cars weighing up to 1 181 kilograms. (2600 lb.)

Tonne-kilometre: The transport of one tonne over a distance of one kilometre.

Agriculture Sector

Zero tillage technique: Refers to the seeding of a crop into untilled stubble by causing no more soil disturbance than opening a slit or very narrow strip of soil just enough to plant the seed. Chemical weed control is an essential part of the system. Any system in which more than 25 percent of the soil surface is distributed is usually not considered as a zero tillage.